Understanding face processing in Autism

An investigation of the perception of faces in high-functioning individuals with autism

Jan-Pieter Teunisse

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Proefschrift

ter verkrijging van de graad van doctor
aan de Katholieke Universiteit Brabant,
op gezag van de rector magnificus, prof. dr. L.F.W. de Klerk,
in het openbaar te verdedigen ten overstaan van een
door het college van dekanen aangewezen commissie
in de aula van de Universiteit op
maandag 23 september 1996
om 14.15 uur

door

Johannes Petrus Wilhelmus Maria Teunisse

geboren op 15 november 1963
te Eindhoven

Promotor:

Prof. dr. B.L.F.M. de Gelder

ISBN 90-361-0009-7

Voorwoord

Dit proefschrift is het zichtbare resultaat van enkele jaren onderzoek als AiO bij de sectie Functieleer aan de Katholieke Universiteit Brabant. Niet alles uit die periode is terug te vinden in dit proefschrift. In de eerste plaats zijn de pilots en oriënterende onderzoeken die ik heb gedaan niet verder gekomen dan een uitdraai op de computer of een presentatie op een congres. Die onderzoeken zijn echter zeker van waarde geweest, want al experimenterend vond ik de richting die ik uiteindelijk uit wilde. In dit boek wordt ook niets vermeld over de praktische omstandigheden waarin het onderzoek heeft plaatsgevonden. Een proefschrift is daar ook niet voor bedoeld, denk ik, maar de omstandigheden zijn wel heel bepalend voor hoe ik uiteindelijk op het project terug kijk. Zoals waarschijnlijk elke promovendus kende ik mijn momenten van inspiratie en van moedeloosheid, en ook ik ken nu de strijd die je met jezelf moet voeren om een leesbare tekst op papier te krijgen. Het meest bijzondere van dit project vind ik echter dat ik als functieleerpsycholoog in aanraking kwam met autistische jongeren. Mijn interesse ging duidelijk verder dan alleen een nieuwsgierigheid naar de resultaten. Het zijn vooral de 'tussendoor'-gesprekjes met de jongeren die indruk op me hebben gemaakt: een jongere die me onverwacht vreemde vragen gaat stellen; een jongere die maar doorpraat over zijn obsessie en bijna niet te stoppen is; de ontdekking dat ook iemand met autisme blij kan zijn om je te zien. Het heeft mijn beeld van autisme minstens zo veel gevormd als de resultaten van mijn onderzoek.

Er zijn verschillende mensen die ik wil bedanken voor hun bijdrage aan dit proefschrift. Allereerst promotor Bea de Gelder, niet alleen voor haar begeleiding, maar ook omdat ze me in staat stelde de meest recente ontwikkelingen op onderzoeksgebied van dichtbij mee te maken op congressen die ik mocht bezoeken. Ook de andere leden van de Sectie Functieleer wil ik bedanken: Jean Vroomen en Paul Bertelson voor hun waardevolle adviezen op onderzoeksgebied; Monique van Zon, Rosemarie Irausquin en Theo Popelier voor hun betrokkenheid bij mijn reilen en zeilen als AiO. Petra Piree, Steef Sinkeldam en Elles Mulder dank ik voor de hulp bij het testen van de kinderen en volwassenen.

Verschillende mensen hebben me ondersteund bij de praktische kant van het onderzoek en ook hen bedank ik bij deze. Ben Bergmans heeft tientallen foto's van gezichten (en schoenen) gemaakt die ik heb gebruikt in mijn experimenten. John van de Beesen heeft de gebruikersvriendelijke computerprogramma's geschreven die de taken bestuurden en de resultaten overzichtelijk wegschreven in datafiles. Ook de andere leden van de Sectie Automatisering en Onderzoeksondersteuning (Mijndert van der Stelt, Ton Aalbers, Paul Vermaseren, Bert Bastiaansen, Charles Rambelje, Ad Schepens, Jos Rovers, Peter van Vugt, Nico Willemsen, Rien Deijkers, Peter Flohr, Ineke Grbic en Rob Vossen) waren zeer behulpzaam bij het maken van de onderzoeksop-

stellingen. Susan Struycken en Nettie van Bree tenslotte waren de onmisbare (en gezellige) krachten van het secretariaat.

Geen psychologisch experiment zonder proefpersonen, en daarom bedank ik speciaal de mensen die zich beschikbaar hebben gesteld om aan de onderzoeken mee te doen. Dat zijn om te beginnen een groot aantal studenten van de KUB, die het mij mogelijk maakten om de taken te ontwikkelen. Verder dank ik de leiding, ouders en leerlingen van Basisschool De Borne, Basisschool De Helle, de Michael Scholengemeenschap en de Norbertus MAVO, allen te Tilburg, omdat ik op deze scholen de gegevens heb mogen verzamelen voor de controlegroepen.

In het eerste stadium van mijn project ben ik op verschillende plaatsen in Nederland geweest om taken bij autistische jongeren af te nemen. Ik dank de leiding, ouders en pupillen van de Herman Broerenschool (Rosmalen), Medisch Kinderhuis Apeldoorn, Kinderhuis Reek, en de School voor VSO de Ortolaan (Heythuysen) voor hun bereidwillige medewerking aan deze onderzoeken. Voor de laatste fase van het project heb ik een serie computertaken ontwikkeld die ik in een geconcentreerde periode heb afgenomen in het Dr. Leo Kannerhuis te Oosterbeek. Dankzij de voortreffelijke coördinatie van Cisca Aerts, de flexibele opstelling van de groepsleiding, de medewerking van de ouders, en de inzet van de jongeren, is deze onderzoeksperiode vlekkeloos verlopen. Ook dank ik Hans Berger voor zijn enthousiaste en kritische commentaar op mijn onderzoek; ik heb dat als zeer stimulerend ervaren.

Uit mijn afstudeeronderzoek naar stress weet ik nog dat sociale ondersteuning een van de belangrijkste factoren is voor een goed functioneren. Daarom wil ik mijn familie en vrienden bedanken, waarvan ik er enkelen speciaal wil noemen. Op de KUB zorgde vooral Eefje Vonken voor de nodige sociale ondersteuning tijdens de dagelijkse koffiepauzes. Wout Croonen hielp mij het wetenschappelijke wereldje beter te begrijpen dankzij zijn theatrale beschouwingen. Dat ik naast het proefschrift ook nog een andere uitdaging aan kon gaan dank ik aan de inspirerende samenwerking met Susan Dingarten, die veel energie en tijd in onze theaterproductie heeft gestoken. De drukke werkzaamheden maakten mij een beetje een onzichtbare bewoner van de Wassenaerlaan 34, maar het was prettig om aan een proefschrift te werken met leuke mensen om me heen.

Mijn ouders bedank ik voor de onvoorwaardelijke steun die ik heb gekregen bij alles wat ik ondernam. Tenslotte bedank ik Riëtte van Rooy, die tijdens het schrijven heel dicht bij me heeft gestaan. Dankzij haar heb ik me ondanks deze solitaire bezigheid nooit alleen gevoeld.

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1. Introduction

Several studies have shown that some aspects of the face perception of autistic individuals are selectively impaired. Most of these studies were conducted to determine which face processing abilities are impaired and which are not. However, very few studies have examined *how* these processes may be affected. The focus of the present thesis is on the nature of face processing, in order to understand how the selective impairments can emerge in autism.

In the first experimental study reported in this thesis, a clinical test battery of face perception was administered to get an impression of which stages in the face processing system are deficient in the autistic group (Chapter 2). The question whether facial expressions are perceived categorically by normal adults and children is examined in Chapter 3; these findings are then compared to expression recognition in autistic individuals (Chapter 4). Chapter 5 concerns configural and holistic encoding of faces in autistic individuals, which was studied by examining the results of inversion and composite tasks. In Chapter 6, face and expression superiority effects in autistic subjects were studied in a memory search task. The main findings of the experiments are summarised and discussed in Chapter 7.

Before the experiments are described, some background information concerning autism and face processing are presented in the introductory chapter. Both autism and face processing are topics that have been studied extensively, but for this purpose, only those studies that are considered relevant for understanding the specific face processing impairments in autistic subjects are reviewed. In the first section, the diagnostic criteria that define the autistic syndrome and theories concerning the possible underlying deficit are discussed. This is followed by a chronological overview of studies of face perception in autistic individuals. These findings from the literature are then placed in the context of theoretical models of normal face processing. This latter concerns the functional architecture of face perception, the mental representation of faces, the perception of facial expressions, and the normal development of face processing abilities. The introduction concludes with the research questions, and the strategies that were employed to answer these questions.

1.1. AUTISM

1.1.1. Diagnostic criteria

Most introductions on the subject of autism start with Kanner's publication in 1943, in which he gives detailed case descriptions of eleven autistic children. However, the label 'autistic' was not introduced by Kanner, and autistic children had already been described some years earlier, between 1937 and 1940, in internal reports of the Nijmegen Pedological Institute (Meyknecht, 1971). Kanner borrowed the label 'autistic' from Bleuler, who introduced the term in 1911 to refer to the withdrawal into fantasy of schizophrenic patients (J. Wing, 1976). Around the same time as Kanner's paper, Asperger (1944) used a similar label ('autistic psychopathy') to describe a group of children with behavioral symptoms that were very much like those in Kanner's study. This use of one label for two different disorders, autism and schizophrenic withdrawal, was not without problems, as Rutter (1978) pointed out. First, Bleuler's schizophrenic patients actively *withdrew* from social relationships, whereas Kanner's autistic children failed to *develop* social relationships. Second, Bleuler's definition suggests a rich fantasy life, whereas Kanner reported a lack of imagination in autistic children. Finally, a confusing link with schizophrenia was made.

The reason Kanner's paper had such an impact was the fact that in addition to the detailed case descriptions of autistic children, he also offered a theoretical account for the disorder. This account turned out not to be valid in all respects, but it was a good starting point for the development of diagnostic criteria. Kanner considered the following behavioral abnormalities as cardinal features of the autistic syndrome:

- *'extreme autistic aloneness' from birth;*
- *an anxiously obsessive desire for sameness;*
- *a fascination with objects;*
- *a lack of eye contact with other people;*
- *impaired language development: mutism, delayed echolalia, noncommunicative use of speech after it develops;*
- *a lack of imagination;*
- *repetitive and stereotyped play activities;*
- *'islets of ability': good rote memory, precise recollection of complex patterns and sequences.*

Later, Eisenberg and Kanner (1956) proposed that 'extreme aloneness' and 'preoccupation with the preservation of sameness' were the two essential symptoms of autism, from which the other problems followed. The early onset of the syndrome, before the second year of life, was a third essential condition that differentiated autism from other psychotic conditions which have a later onset. However, Wing and Attwood (1987) pointed out that the clinical picture of the syndrome should be far more important for diagnosis than the age of onset.

Asperger's definition of autism was much broader than that of Kanner, including cases that were more severe and cases that were closer to normal. It was only much later that the label 'Asperger's syndrome' was commonly used for a subgroup of high-functioning autistic children with unusual social relatedness but good language competencies (Wing, 1981a). Several authors have questioned the validity of the label 'Asperger's syndrome' as being distinct from autism (Schopler, 1985; Volkmar, Paul & Cohen, 1985; Szatmari et al., 1986), but Ozonoff, Rogers, and Pennington (1991) found evidence that there might be an empirical distinction between the two clinical populations, in that only the autistic group and not the Asperger group shows a deficit in 'theory of mind' (see section 1.1.2.). The label has now been included in ICD-10, the diagnostic system of the World Health Organisation (WHO, 1987).

In the years following the first clinical descriptions of autism, there was much discussion about the diagnostic criteria, partly because of the confusion between autism and other psychotic disorders in childhood. In many studies, autistic and schizophrenic children were placed in the same category, 'psychotic', even though the clinical picture was different (Hintgen & Bryson, 1972). On the other hand, attempts were made to order the confusing variety of symptoms found in psychotic and autistic children by defining new subclassifications, but these appeared to overlap to a great extent and were, therefore, not useful (Wing & Attwood, 1987). In an attempt to extract the defining characteristics of autism, Rutter (1966) and Rutter and Lockyer (1967) studied 63 autistic children and a control group consisting of children with emotional and behavioral disorders. This led to a definition of autism in terms of four essential criteria (Rutter, 1978):

- *an onset before the age of 30 months;*
- *impaired social development;*
- *delayed and deviant language development;*
- *insistence on sameness.*

This list is similar to the 'Triad of Impairments' that was proposed by Wing and Gould (1979): impaired social development, impaired verbal and nonverbal communication, and impaired imagination. Rutter's criteria for autism describe the main features that are now used in the two most influential systems of classification, the Diagnostic and Statistical Manual (DSM-III-R) of the American Psychiatric Association (APA, 1987) and the International Classification of Diseases (ICD-10) of the World Health Organisation (WHO, 1987). Developmental disorders that are related to autism but do not meet the full criteria for that condition are classified as atypical autism (ICD-10) or atypical pervasive developmental disorder (DSM-III-R).

Because there is no clear boundary between the diagnosis of typical autism and atypical autism, estimates of the incidence vary with the strictness with which the criteria are used, from about 5 autistic children per 10,000 (Lotter, 1966) to 10 per 10,000 (Bryson, Clark & Smith, 1988). More boys than girls are diagnosed as autistic, and this is related to mental retardation: in a low ability autistic population, the estimates of the male/female ratio vary from 3:1 (Lord, Schopler & Revicki, 1982) to 2:1 (Wing, 1981b), while this ratio is estimated to vary from 5:1 (Lord et al., 1982) to 15:1 (Wing, 1981b) in high ability autistic people.

In addition to the diagnostic systems, Wing and Gould (1979) developed a system of subclassification within the autistic spectrum based on the qualities of social interaction. The abnormal social interaction behaviours were divided into three subtypes, all with different clinical pictures: aloof, passive, and active-but-odd. The aloof group is the most severe of the three. Children in this group show no interest in other people. Some of them might like simple physical contact with adults, such as cuddling, but they are not interested in the social aspects of the contact. They show no overt signs of affection for other people. The passive group is also indifferent to social contact with other people, but unlike the aloof children, they will allow others to approach them. However, they will not spontaneously seek contact themselves, and social contact will always remain superficial. The active-but-odd group seems to make social approaches to others, but these approaches are odd and inappropriate. Their social interaction tends to consist of repeating the same questions over and over again or talking obsessively about their preoccupations. They show no interest in the thoughts and feelings of other people. The clinical picture of a particular child with autism may change as the child grows older, e.g., from aloof to active-but-odd, and a child may manifest the behaviour of different subtypes in different situations.

Another type of clinical picture may arise as a result of intellectual progress (Wing, 1988). Autistic individuals with normal intelligence may acquire superficial knowledge of social behaviour through intellectual learning, which makes their behaviour appear to be more adaptive. However, their social understanding will always remain rationalistic and superficial, and they will never be able to understand social behaviour empathically or through intuition.

1.1.2. Theories of autism

Autism is a developmental disorder that affects a wide range of behavioral features. These features are considered to cluster together to constitute a single syndrome that can be differentiated from other psychiatric conditions. The clinical picture of autism is different for every individual, and even within the same individual, it may be altered dramatically through life or situational changes. The wide variety of handicaps associated with autism makes it very difficult to define which symptoms are specific for autism or what deficit is central to autism. However, the existence of pure autism in otherwise nonretarded individuals suggests that there might be a specific part of the brain that is responsible for the autistic disorder (Frith, 1989). This impairment can have several anatomical, physiological, or chemical causes, and in most autistic children, other areas of the brain will also be affected.

The underlying pathology is not yet known, and this is seen as the main reason for the difficulties and disagreements over the diagnostic criteria (Wing & Attwood, 1987). It is therefore important that theories are developed which attempt to explain the nature and origin of the autistic syndrome. Nowadays, it is commonly believed that autism is a primary neurological dysfunction, however, interpretations differ as to what could be central to the syndrome psychologically.

Four recent (neuro-)psychological accounts are discussed in the following section.

The Socio-Affective approach. According to Kanner (1943), "the outstanding, 'pathognomonic', fundamental disorder is the children's inability to relate themselves in the ordinary way to people and situations from the beginning of life." He considered this "fundamental disorder" to be innate: "We must, then, assume that these children have come into the world with innate inability to form the usual biologically provided affective contact with people, just as other children come into the world with innate physical or intellectual handicaps." Asperger (1944) also suggested that the central disorder of autism is a disturbance of contact at some deep level of affect and/or instinct. In fact, this belief was the reason for both to choose the label 'autistic', which refers to the Greek word for 'self'. The title of Kanner's paper, "Autistic disturbances of affective contact", also indicates that 'autistic aloneness' (Kanner, 1943) was thought to be central to the syndrome.

However, Kanner also indicated that parents of autistic children, although highly intelligent and professionally qualified, were unsociable, undemonstrative, formal even in their closest relationships, detached, obsessional, and lacking in warmth. This led to an emphasis on psychogenic explanations in the years after Kanner's first publication. These early theories stressed the importance of family and environmental factors in the development of the autistic syndrome; the so-called 'refrigerator mother' in particular became a common topic of investigation (Mahler, 1952). The impairment of affective and social contact was seen as the result of fear of a threatening outside world (Bettelheim, 1967; Bosch, 1970; Ruttenberg, 1971; Tinbergen & Tinbergen, 1972; Harper & Williams, 1975). As no intellectual impairments were assumed in the autistic child (Kanner, 1943), it was thought that once psycho-analytic therapy had cured the disturbance in social interaction, normal cognitive development would be possible.

However, epidemiological studies failed to find differences in social environment (Ritvo et al., 1971; Schopler et al., 1979; Wing, 1980) or parental care and personality (Cox et al., 1975; Cantwell et al., 1978; McAdoo & DeMeyer, 1978) between autistic and control children, and this has discredited psychogenic explanations. The theoretical models that followed all acknowledged the importance of social impairments in autism, but most considered other factors as the primary manifestations. It was not until the late 1980s that theories were developed which again considered the deficient processing of affective information as the cardinal feature of the autistic syndrome (Fein et al., 1986; Baron-Cohen, 1988; Dawson, 1989; Mundy & Sigman, 1989; Rogers & Pennington, 1991). The most prominent defender of this approach is probably Hobson, who described a detailed theory of affective disorder in autism in his book "Autism and the development of mind" (Hobson, 1993).

The principal thesis in this book is that the essence of autism is a severe disturbance in intersubjective personal engagement with others (p. 194). This disturbance in autistic individuals is strongly suggested by experimental and observational evidence of abnormalities in the perception of emotional expressions in other people (Hobson, 1986a, 1986b; Braverman et al., 1989; van Lancker et al., 1989; Ozonoff, Pennington & Rogers, 1990). Furthermore, the emotional expressiveness in autistic people is abnormal (Herzig, Snow & Sherman, 1989; Macdonald et al., 1989; Yirmiya et al., 1989). According to Hobson, there is normally an intimate link between perception and expression of emotions. Social perception is 'relational': it is intrinsically connected to feelings and action. For example, when a facial expression is perceived, this is not the perception of a meaningless configuration upon which a psychological meaning is attributed intellectually, but the meaning itself is directly perceived and this is accompanied by an affective response. "To perceive a smile is inclined to feel certain things. (...) The infant needs a sensitivity to the temporal patterns and 'activation contours' of personal events (Stern, 1985), and innately determined propensities to give organised, bodily expressive actions and gestures in response" (Hobson, 1993, p. 40). In autistic children, this social perception mechanism is disturbed. It limits their capacity for and experience of 'personal relatedness', the interpersonal relatedness between the child and one or more other persons which is crucial to the understanding of the nature of people. Moreover, it severely constrains their ability to develop cognitive, linguistic, and social capacities, as these depend to a great extent on the relatedness to other people. In his book, Hobson gives an extensive account of how this socio-affective impairment leads to the characteristic behavioral pattern of autistic individuals.

Leslie and Frith (1990) argue that there is little evidence for a basic affective disorder in autism as proposed by Hobson in an earlier paper (Hobson, 1990). They cite studies that report that at least half of the parents had suspected nothing abnormal in their autistic child's first year (Ornitz, Githrie & Farley, 1977; Newson, Dawson & Everard, 1984). Moreover, in a study of children with problematic social behaviour in the first year, none were found to be autistic some years later (Knobloch & Pasamanick, 1975). Social impairments at the age of two or older were found to be more indicative of autism. According to Leslie and Frith (1990), "this pattern suggests that there is a specific and late-emerging social impairment that can be distinguished from a general delay of social responsiveness. This delay is caused perhaps by mental retardation, appears early, and does not necessarily presage autism" (p. 124). Another argument against a basic affective deficit which they mention is the autistic's performance on a picture-sequencing task (Baron-Cohen, Leslie & Frith, 1986). In this task, the subjects were asked to make up a story using four pictures of situations. There were three story types: causal-mechanical, social-behavioral, and intentional. Autistic children performed best on the causal-mechanical stories, less well on the social-behavioral stories, and performed at chance level on the intentional stories. All the stories were supposed to have some emotional content, which suggests that the results cannot be explained by a basic affective disorder. Instead, Leslie and Frith (1990) propose a basic cognitive disorder in autism, a deficit in 'theory of mind'. This cognitive disorder produces the secondary consequences, including affective impairments and disturbances of social and communicative behaviour.

The Theory of Mind approach. 'Theory of mind' describes the ability to attribute mental states with content to other beings (Premack & Woodruff, 1978). These mental states concern beliefs and desires rather than emotions, and are always about something (i.e., I believe that x, and you desire that y). This aboutness of mental states is termed its intentionality (Brentano, 1874). With a 'theory of mind', it becomes possible to make sense of the social world, as it is used to both explain and predict another person's behaviour (Baron-Cohen, 1988).

The first 'theory of mind' studies were conducted by Premack and Woodruff (1978), who investigated the attribution of mental states in chimpanzees. Bretherton and Beeghly (1982) introduced the term in developmental psychology, generating numerous studies of children's developing ability to understand other people's perceptions, discriminate appearance and pretence from reality, take account of other's beliefs, emotions and intentions, and acquire the language with which to talk about such matters (Whiten & Perner, 1991). These studies show that children become able to conceive their own states and the mental states of others in the first few years of life. The 4-year-old has developed a 'theory of mind': the child is able to infer unobservable states in himself and in others, and to use such attributions to explain and predict behaviour.

Baron-Cohen, Leslie, and Frith (1985) were the first to use a 'theory of mind' paradigm in studies with autistic children. In their experiment, two dolls, Sally and Ann, were used in a social scenario. Sally puts a marble in a basket and goes out for a walk. While Sally is gone, Ann transfers the marble from the basket to a box. When Sally returns, the child is asked: "Where will Sally look for the marble?" While most of the normal and Down's syndrome children correctly pointed to the basket, the place where Sally would believe the marble was, most high-ability autistic children pointed to the place where the marble actually was. This suggests that they were not able to understand other people's mental states and to predict their behaviour on this basis. Similar results were found in studies that used slightly different paradigms (Leslie & Frith, 1988; Baron-Cohen, 1989; Perner et al., 1989).

Leslie (1987) proposed a metarepresentational model to explain why the development of a 'theory of mind' is disturbed in autistic individuals. He makes a distinction between first- and second-order representations. First-order representations are mental states that contain information about situations in the real world, which can be validated or disproved by comparing their content with one's experience (e.g., "the bananas are in the red box"). Second-order representations, or metarepresentations, decouple a first-order representation from reality by taking it as an element of a proposition (e.g., "Sarah believes that the bananas are in the red box"). These metarepresentations are critical for the capacity of pretend play and the development of a 'theory of mind'. According to Leslie's model, "autistic children are impaired and/or delayed in their capacity to form and/or process metarepresentations, and this impairs (/delays) their capacity to acquire a theory of mind" (Leslie, 1991, p. 73). The ability to form metarepresentations is associated with a decoupling mechanism (Leslie, 1987) or a 'Theory of Mind module' (Leslie, 1991), which is thought to be specifically impaired in autistic children. Frith (1989) believes that Leslie's theory of a specific neurological impairment of an innate, relatively late-maturing decoupling mechanism can explain Wing's Triad of Impairments better than any other theory. Impairments of social interaction, communication, and imaginative play can all be explained as a result of a single 'theory of mind' deficit. However, she points out that a deficit of the decoupling mechanism is one example of how the ability to form and handle metarepresentations could be impaired. Other subgroups of autistic children may have an intact decoupling mechanism (or ToM module), but be impaired in their metarepresentational ability for other reasons. Moreover, the theory cannot explain the additional symptoms that are observed in autistic individuals, such as the 'islets of abilities' and the repetitive behaviours. Therefore, a more comprehensive explanation of autism is needed.

The Central Coherence approach. Frith (1989) proposed that a central cognitive dysfunction in high level processing is the basic underlying impairment in autism. In her book "Autism: explaining the enigma" (1989), she argued that a weak drive for central coherence of information causes the great variety of symptoms seen in autistic individuals. Information is processed fragmentarily because an automatic cohesive force for coherence and meaning is impaired.

The main arguments for the weak central coherence hypothesis are based on experiments in which task performance depends on the processing of information as meaningful or coherent units. A first example is the performance of autistic children on the Embedded Figures test (Shah & Frith, 1983). In this task, a small figure must be detected in an embedding context. For normal children, this is a difficult task because the spontaneous tendency to see only the forcefully created Gestalt that camouflages the target pattern is hard to resist. Autistic children, however, perform remarkably well on this task, suggesting that they are less captivated by the embedding context. Shah and Frith (1993) also found evidence of weak central coherence in autistic children in an experiment in which systematic variations of the Block Design task were given. They found no differences between autistic and control children on manipulations of spatial orientation of the block design (obliqueness and rotation), but autistic children performed better on unsegmented designs than did the controls. According to Shah and Frith, this suggests that they are better than controls in segmenting a strong Gestalt into parts. Weak central coherence was also found in verbal memory tasks, where autistic children were weak in the organisation of verbal material into meaningful chunks. Hermelin and O'Connor (1970) presented slowly read out strings of words to autistic and non-autistic children. Some of the word strings contained sentence-like parts. The task was to recall as many words as possible. The control group always remembered the meaningful word strings better than the meaningless ones, whereas the autistic children were not sensitive to meaningfully organised word strings. In another experiment, in which jumbled as opposed to normal sentences had to be remembered, autistic subjects only exhibited a slight advantage in recalling normal over jumbled sentences.

Frith (1989) gives an account of how weak central coherence can explain other autistic features, such as stereotyped movements and thoughts, language and communication impairments, and impairments in the expression and perception of emotions. However, it is not always clear what the theory would predict in certain experiments. For example, Shah & Frith (1993) argue that "one expectation from this postulated facility is a relative preference for processing local as opposed to global features". This prediction was tested by Ozonoff et al. (1994), using the H&S task developed by Navon (1977). In this task, a large letter composed of small letters is presented. The small letters can be compatible or incompatible with the large letter. The task is to respond to the small or to the large letters. Like the controls, autistics were faster in responding to the large letters than to the small letters, and faster on compatible trials than on incompatible trials. Ozonoff et al. argue that these findings undermine Frith's central coherence theory (1989), as the autistic group did not demonstrate difficulties in processing the global features of a stimulus or exhibit superiority in processing local features. However, it is also possible that this kind of global-local task is not an appropriate operationalisation of central coherence. Maybe the drive for central coherence does not imply an automatic preference for local as opposed to global features, or maybe not all sorts of global patterns are related to greater central coherence. Both the Block Design task and Embedded Figures test are assumed to be related to the concept of central coherence because "in both tasks designs with a strong Gestalt quality have to be segmented into constituent parts" (Shah & Frith, 1993, p. 1352). However, a Gestalt can be defined in at least two ways. In the Block Design task, a Gestalt can be understood as the result of a set of organisational principles, such as the laws of good continuation, grouping and figure-ground segregation. In the Embedded Figures task, it is more appropriate to define a Gestalt as the configuration of a familiar and/or meaningful stimulus. The global letter pattern in the H&S task seems to be related to neither of these interpretations of Gestalt. This shows that although the 'central coherence' concept may have a strong intuitive appeal, its operationalisations need more clarification.

The Executive Function approach. Ozonoff, Pennington and Rogers (1991) proposed that deficits in executive function may be central to the autistic syndrome. Executive function (Luria, 1966; Duncan, 1986) is a cognitive construct used to describe goal-directed, future-oriented behaviours that are mediated by the frontal lobes. These behaviours involve planning, inhibition of prepotent responses, flexibility, organised search, and working memory (Goldman-Rakic, 1987). Evidence for a deficit in executive function was found in autistic preschool children (McEvoy, Rogers & Pennington, 1993), autistic children and adolescents (Prior & Hoffman, 1990; Ozonoff, Pennington & Rogers, 1991), and autistic adults (Steel, Gorman & Flexman, 1984; Rumsey, 1985; Rumsey & Hamburger, 1988, 1990). Executive function, in contrast to the 'theory of mind' capacity, seems to be impaired in both high-functioning autistic individuals and individuals with Asperger's syndrome (Ozonoff, Rogers & Pennington, 1991). The most frequently used tests for measuring executive function are the Wisconsin Card Sorting Test, which requires the generation and alteration of classification rules, and the Tower of Hanoi, which requires problem solving and planning. Other tests which are used are a maze learning task, in which the subject must learn by trial and error to find the correct route through a matrix of metal plates, and the Rey-Osterrieth Complex Figure (Rey, 1959), which consists of copying a complex figure and drawing it later from memory. McEvoy, Rogers, and Pennington (1993) administered executive function tests that were designed for preschool children: the A not B error test (Piaget, 1954), a delayed response task (Jacobsen, 1935), a spatial reversal task (Kaufman, Leckman & Ort, 1989), and an alternation task (Goldman-Rakic, 1987).

Autistic individuals show marked impairments on these frontal lobe tasks, but autism is not the only disorder that is associated with a deficit in executive function. Children with attention deficits/hyperactivity disorder (Chelune et al., 1986), conduct disorder (Leuger & Gill, 1990), early-treated PKU (Welsh et al., 1990) and Tourette Syndrome (Gedye, 1991; Pennington, 1991; Stoetter et al., 1992) all exhibit executive function deficits. One reason for the involvement of impaired frontal lobe functions in many disorders is that the frontal lobe is a large and complex structure with many connections to other brain regions. The consequences of frontal lobe damage depend on the exact location of the lesion. Bishop (1993) suggests that the neurological model for autism that was proposed by Damasio and Maurer (1978) might indicate which frontal brain area could be specifically impaired in autism. This model, which is based on an analogy of behavioral symptoms in brain damaged adults, such as motor disturbances, language impairments, and disturbances in goal-directed activity, suggests that brain regions that receive dopaminergic input from mesencephalic neurons may form the underlying system that is affected in autism. The primary abnormality of the brain would thus be in the part of the brain where the dopaminergic projections originate

(Coleman & Gillberg, 1985). The neural structures that are affected are the ring of mesolimbic cortex located in the mesial frontal and temporal lobes, the neostriatum, and the anterior and medial nuclear groups of the thalamus. Although this model is rather speculative, as it is based on indirect evidence, it predicts which area in the frontal lobe might specifically be damaged, and this might distinguish autistic impairments in executive function from other disorders.

Another research strategy to determine which disturbances in executive function are specific to autism is to administer tests that tap an isolated component of the complex executive function construct. Ozonoff et al. (1994) rightly remark that most clinical neuropsychological tests of executive function require several abilities for successful performance. This makes it impossible to determine which ability is specifically impaired when performance on such tests is poor. They suggest that information-processing paradigms from cognitive psychology can be useful in tapping the separate components of the construct. Another advantage of these methods is that performance is usually recorded by computer, resulting in precise reaction time and accuracy measures. In their study, they used the Go-NoGo task and the H&S task to examine, in separate conditions, some of the most important cognitive operations that are required in executive function tasks: neutral inhibition, prepotent inhibition, cognitive shifting, and local-global processing. They found a specific pattern of strengths and weaknesses among these components. Shifting cognitive set appeared to be most impaired in autistic subjects, while inhibition of a prepotent response was also difficult for them. Inhibition of neutral responses and local-global processing were not different from a control group.

1.1.3. Conclusions

Autism is a complex developmental disorder for which the underlying deficit is not yet known. The main diagnostic symptoms are impaired social relationships, impaired verbal and nonverbal communication, and impaired imagination, with an onset before the age of three. Recent theories of autism have proposed socio-affective disability, impaired theory of mind, weak central coherence, and impaired executive function as the core problem of the syndrome. The complexity of the disorder requires a theory that is broad enough to encompass the variety of symptoms seen in autistic individuals. On the other hand, exact operationalisations of the proposed theory are necessary to make scientific validation possible. In most cases, this would require a theoretical construct to be broken down into its component functions which can then be examined separately. Evidence from several disciplines, including clinical observations and (neuro-)psychological studies, should provide supplementary support for a proposed theory. At this time, none of the above-mentioned theories is able to satisfactorily account for all the behavioral symptoms seen in autism, but each of them contributes to a better understanding of the disorder. In the present thesis, no explicit position in favor of one of the theories of autism is taken in advance, but some of the paradigms can be interpreted as operationalisations of a component function of one of the theories.

1.2. AUTISM AND FACE PERCEPTION

In 1978, Langdell proposed tests of face recognition as a new approach to the study of autism. He was, however, not the first to use this approach: in 1973, face perception experiments were already reported by Jennings in his Ph.D. thesis (Weeks & Hobson, 1987). However, Langdell's paper had more impact and inspired other researchers to investigate face perception in autistic individuals. A majority of these studies appeared in the same journal that published Langdell's first paper, the Journal of Child Psychology and Psychiatry.

In the following section, a chronological overview is given of these face processing studies in autism.

1.2.1. Chronological overview

In Langdell's study, two age groups (mean age: 9.8 yrs and 14.1 yrs) of normal, subnormal and autistic children were tested for their ability to recognise the faces of peers in seven masking conditions and in the inverted orientation. There were two important findings. First, the autistic subjects relied on different parts of the face for recognition than the control groups did. The control subjects found the upper part of the face the most helpful, whereas the young autistic children performed better on the lower part and the older autistic children showed no preference for any part. The second remarkable finding was that the autistic children performed relatively well on inverted photographs: the older autistic children were better than their controls in recognising peers from inverted photographs, and the younger autistic children were as good as their controls in this condition. Langdell suggests that the results may indicate that the face is not perceived as a social stimulus but as a complex visual pattern. Another possible explanation he puts forward is that young autistic children find it difficult to extract the full meaning from speech as a result of a central cognitive deficit, and this may draw their attention to the mouth region of the face. Furthermore, the relative preference for the lower part of the face might be related to an impaired ability to understand the social meaning of the eye region. It was suggested that the superior performance of the older autistic children on faces that were presented upside-down resulted from a deviant scanning strategy in this group.

In the second half of the 1980s, Hobson conducted a series of experiments to examine a possible emotion-specific deficit in autistic children. In the first study (Hobson, 1986a), facial expressions of 5 emotions had to be matched to videotapes of emotional gestures, vocalisations, and situations with emotional content (the emotion condition). This cross-modal matching of expression was done to ensure that recognition was based on the meaning of the emotion rather than on the perceptual configuration of the stimuli. The faces were schematic drawings (experiment 1) or photographs (experiment 2). In a control condition (the things condition), a drawing of a situation had to be matched to nonemotional movements, sounds, and contexts. The subjects in experiment 1 were 23 autistic adolescents (age: 9;11-19;6 yrs). Their performance was compared to that of 23 normal children matched on nonverbal IQ, 11 normal children matched on verbal IQ, and 11 retarded adolescents matched on both chronological age and nonverbal IQ. In experiment 2, the same autistic subjects were tested one year later on the emotion condition with photographs of facial expressions. The results showed that the autistic adolescents were impaired in the emotion condition but not in the things condition. Hobson suggests that this indicates that autistic adolescents are specifically impaired in the recognition of emotional expressions. Normal performance in the things condition indicates that there is no general impairment in perceptual or semantic categorization as applied to visual and auditory input.

In a further study (Hobson, 1986b), subjects had to match drawings of 5 gestures to videotapes of gestures, vocalisations, or facial expressions. The subjects were 13 autistic adolescents (age: 11;11-21;0 yrs) and 13 retarded adolescents matched on age and nonverbal IQ. Their performance on matching videotapes of gestures to drawings of gestures was at ceiling, but in the vocal and facial expression conditions, autistic subjects made more errors than the control group. The performance of the autistic group was correlated with verbal ability. Hobson suggests that these results indicate that the deficit in emotion recognition is not limited to any given mode of expression, but that the coordination of emotions in faces, gestures, and vocalisations is impaired.

Weeks and Hobson (1987) found still more evidence for impaired recognition of facial expressions in a task in which photographs of faces that differed in several respects (sex, facial expression, type of hat, and age) had to be categorised on a self-chosen dimension. Fifteen autistic subjects (age: 8;5-22;0 yrs) and 15 retarded subjects matched on verbal IQ completed the task. Both groups considered sex as the most salient feature for sorting. However, when type of hat and facial expression were the only dimensions on which categorisation was possible, most autistic subjects, in contrast to the controls, preferred sorting by type of hat over sorting by facial expression. Many autistic subjects did not sort by facial expression at all, even if this was the only discriminant feature, and had difficulties when the instructions were explicitly to sort according to expression. Weeks and Hobson reported that a similar investigation with comparable results had been conducted by Jennings (1973). The results are interpreted as an indication that the impairment in autistic subjects is specific for recognition of emotions in the face, while other physical attributes of the face are more easily perceived and discriminated.

The specificity of an emotion deficit in face perception was further examined in a study by Hobson, Ouston, and Lee (1988). Seventeen autistic subjects (age: 14;4-25;10 yrs) and 17 retarded subjects matched on age and verbal IQ were administered a matching task for identity and expression. The task was presented in 3 masking conditions: full-face, blank-mouth, and blank-mouth-and-forehead. Surprisingly, the autistic subjects performed better than the control group on the full-face presentation of the facial expressions, although this difference was not significant. As the available cues were reduced from full-face to blank-mouth-and-forehead in the expression condition, the performance of the autistic group declined more than that of the controls. In the identity matching task, this decline was similar for both groups. Correlations between performance on the two conditions (identity and expression) were higher for the autistic individuals. In a second experiment, the full-face photographs were presented upside-down. In this inversion condition, autistic subjects were superior in both identity and expression matching. According to the authors, these results provide evidence for specific qualitative differences between autistic and control subjects in the processes or strategies of emotion recognition. The emotional content of an expression seems to be processed to a lesser extent, but the inversion results, which are in line with Langdell's findings (1978), suggest that autistic subjects also use different processing strategies in identity recognition.

Braverman, Fein, Lucci, and Waterhouse (1989) continued on Hobson's line of research in studying affect comprehension with photographs of faces. Fifteen children with pervasive developmental disorder (PDD, age: 7;5-15;0 yrs), 10 of which met the criteria for autism, were compared to 15 normal controls matched on nonverbal IQ and 15 normal controls matched on verbal IQ on matching tasks of facial expression, facial identity, and objects. Furthermore, they studied comprehension of affect labels by asking the subjects which of 4 facial expressions corresponded to a label (e.g., "show me the happy face"). In a free-labelling task the subjects were shown the photographs of the affect-matching task and asked how the person felt. The results showed that the group differences were quite small. PDD subjects inferiorly performed on expression matching and affect comprehension relative to the nonverbal control group, but not relative to the verbal control group. Within the PDD group, expression matching was worst, identity matching somewhat better, and object matching best, while in the nonverbal control group, no differences between these tasks were found. Object matching in the PDD group was correlated with mental age, language, and daily living skills; social matching tasks were correlated with mental age, play, and socialisation. Although the effects were smaller in this study than in the Hobson studies, recognition of the affective dimension of the face was again found to be most impaired in autistic subjects.

Volkmar, Sparrow, Rende and Cohen (1989) investigated the suggestion that the ability of autistic subjects to use the human face as a source of information might be impaired. They administered a series of jigsaw puzzles of human faces that differed in complexity (3, 6, or 9 pieces), familiarity (familiar or unfamiliar faces), and configuration (normal or scrambled) to 16 autistic children and adolescents (age: 9-18 yrs) and 16 retarded controls which were matched on age and nonverbal IQ. Significant main effects were found for all three conditions, but there was no interaction with diagnostic group. The finding that the autistic subjects performed better with familiar than with unfamiliar faces, and better with normal than with scrambled faces, suggests that they at least rely on some aspects of the human face as a source of information.

Tantam, Monaghan, Nicholson, and Stirling (1989) used an 'odd-one-out' task to study the specificity of expression recognition in autistic children (mean age: 12.14 yrs) and retarded controls matched for age and nonverbal IQ. In this task, sets of 4 photographs of faces were shown to the subjects. In the emotion condition, the odd face differed in emotional expression from the other three faces; in the identity condition, the odd face was of a person other than one in the other three photographs. The autistic subjects performed less well than the controls on both conditions, and the interaction diagnostic group x condition was not significant. In a labelling task in which object and emotion words had to be matched with photographs of objects, facial expressions, and inverted facial expressions, there were no differences between the groups on object labelling. When the upright and inverted conditions of facial expression were analyzed together, there was significant interaction of group x orientation: autistic subjects were as good as controls in labelling inverted photographs of expressions, but they were less successful at labelling upright facial expressions. There was no significant correlation between verbal IQ and performance on the labelling tasks. These results suggest that autistic individuals have difficulties recognising and labelling facial expressions, but the 'odd-one-out' experiment suggests that the impairment is not specific to expression recognition. The authors argue that their findings on the inversion condition are consistent with Langdell's observation (1978) that autistic children do unexpectedly well in recognising upside-down faces (the authors were yet not familiar with the study by Hobson, Ouston, and Lee (1988), who also found a comparable result with inverted faces). In the study by Tantam et al., however, the absence of an inversion effect in the autistic group may be due to a floor effect, since even performance on upright faces was very poor.

Macdonald et al. (1989) examined Hobson's assumption that autistic individuals are impaired in their ability to both recognise and produce vocal and facial expressions of emotion. The subjects in their study were 10 high-ability autistic adults (mean age: 27.2 yrs) and 10 normal adults who were comparable on age and nonverbal IQ. The recognition task of facial expression consisted of matching the proper emotional expression (out of 5) to a photograph of a context designed to elicit that emotion. After choosing the expression, the subject was asked to name the emotion. Autistic adults made more errors in both the matching and the naming task. They were also impaired on recognition of emotional speech and were judged to be more odd in their facial and vocal expressions of emotion. An interesting finding was that autistic adults, unlike normal adults, did not find filtered speech more difficult to categorise than comprehensible speech. The authors suggest that autistic subjects might be less affected than normals by transformations or alterations that make stimuli less familiar and/or less meaningful. This is consistent with the good performances of autistic subjects on inverted faces, and this may support the belief that autistic people treat social stimuli more as pure, nonsocial patterns.

The specificity of the emotion perception deficit was tested once more by Ozonoff, Pennington, and Rogers (1990). They conducted an experiment consisting of 4 tasks with 14 autistic children (age: 3.42-10.83 yrs), 14 children matched on verbal MA, and 13 children matched on nonverbal MA. The first task was to sort faces by identity and expression. The second task was a cross-modal task in which emotional intonations had to be matched to 1 of 3 facial expressions. In the non-emotional control condition of this latter task, a sound had to be matched with a drawing of common objects, animals, and actions. The third task was a matching task of objects, facial identity, facial expression, and emotional situations. The final task was a vocabulary task, in which the mother indicated how often certain word categories were used by her child. The results showed that autistic children were only different from children matched on nonverbal MA. They had lower scores on all the tasks. Group x condition interactions were only significant in the matching and vocabulary tasks. In the matching task, the two groups only differed on the object match. Although the interaction in task 1 was not significant, separate analyses of the identity and the expression conditions showed that only the expression condition resulted in lower scores for the autistic children. These findings partially supported the hypothesis of a specific emotion perception deficit. However, Ozonoff et al. argue that if this impairment is considered to be the fundamental deficit underlying autism, than it should be a more robust phenomenon apparent across studies, paradigms, and control groups. Therefore, they consider the affective deficit as neither universal nor specific to autism.

In the issue of the Journal of Child Psychology and Psychiatry that followed, Prior, Dahlstrom, and Squires (1990) expressed further doubt that an emotion perception deficit is specific for autism. They presented a variation of the cross-modal paradigm that Hobson developed in 1986 (Hobson, 1986a): vocalisations, gestures, and drawings of situations with emotional content had to be matched with drawings of facial expressions. A 'things condition' served as the control task. Twenty autistic children (age: 5;4-15;0 yrs) were compared to 20 controls matched on verbal ability. They found no group differences on any task. Emotion perception was correlated with performance on a series of 'false belief' tasks. Furthermore, both emotion perception and false belief tasks were significantly correlated with verbal MA. The authors argue that verbal comprehension factors may be central to the capacity to demonstrate knowledge of the emotional and mental states of others, and their findings are not supportive of the view that deficits in emotion perception or theory of mind are specific to the autistic syndrome.

The contribution of a language factor to facial expression perception was also evident in a study conducted by Smalley and Asarnow (1990), who examined cognitive subclinical markers in autism. The subjects were 9 autistic adults (mean age: 20.3 yrs), 9 siblings, 15 parents, and 3 corresponding control groups. The experiment consisted of 2 language tasks (vocabulary and comprehension), 2 visuo-spatial tasks (block design and line orientation), and 3 face recognition tasks (identity matching, expression matching, and expression labelling). The autistic subjects were not impaired on identity matching, but exhibited an emotion recognition deficit on both expression matching and labelling. However, group differences on both emotion tasks were lost when adjusted for vocabulary differences. Moreover, expression recognition was correlated with verbal abilities in the autistic group while this was not the case in the other groups, suggesting that autistic subjects rely more on verbal strategies in expression recognition.

De Gelder, Vroomen, and van der Heide (1991) examined recognition of unfamiliar faces using a matching task and a recognition task. In the matching task, one or more target faces were shown in every trial, and then a group picture of 4 or more people was shown and the subject was asked to point to the target person(s). The recognition task consisted of a learning set of 16 full-face photographs, and a test phase in which every target face was presented with a distracter face. A picture recognition task of everyday scenes was administered as a control task. The 17 autistic subjects (age: 6;6-16;4 yrs) made more errors on both face recognition tasks than did the 17 controls matched on verbal and nonverbal ability. The study also contained a facial speech test. In this test, subjects were asked to repeat the VCV syllables that a person on a video screen pronounced (e.g., /aba/ or /ana/). There were 3 conditions: in the audio-only condition, only the voice was heard; in the visual-only condition, the sound was deleted from the video; in the audio-visual condition, combinations of conflicting information from the two modalities were presented, resulting in perceptual fusions and blends. The autistic subjects were not different in the visual-only and auditory-only conditions, but they were in the audio-visual condition; they made fewer fusions and blends, indicating that they were influenced to a lesser extent by visual speech. The authors suggest that this might signal a lack of integration between linguistic information coming from different modalities. The impaired face recognition in combination with intact lip-reading is interpreted as favouring the face perception model proposed by Bruce and Young (1986), in which lip-reading and face recognition are supposed to proceed in parallel.

Boucher and Lewis (1992) also found evidence for a deficit in unfamiliar face recognition. In a first experiment, 10 autistic subjects (age: 10;10-16;0) were compared to 10 learning disabled matched on nonverbal IQ, and 10 normal subjects matched on age. In a forced-choice recognition paradigm, the autistic subjects made more errors than both control groups. Performance was not related to nonverbal IQ or age. In a second experiment, consisting of a face recognition task with two learning conditions and a similar object recognition task, 16 autistic subjects (age: 8;11-17;2) were compared to 16 learning disabled matched on verbal IQ. The autistic group made more errors in the face recognition task in both learning conditions: timed (look at every slide for 10 seconds) and discrimination (match every slide to 28 alternatives). They were not impaired on recognising buildings. Autistic subjects spent less time fixating the slides. In recognising buildings, there was a correlation between looking time and performance in both groups. In the face recognition task, this correlation was only significant for the autistic subjects and not for the control group. Verbal ability did not appear to be important for the recognition of unfamiliar faces, unlike previous findings on facial expression recognition. The performance on the control condition suggests that the impairment in unfamiliar face recognition is not part of a wider impairment of visual memory.

At the European Congress on Autism in Den Haag, The Netherlands, Bormann-Kischkel, Amorosa, and von Benda (1992) presented studies that were similar to the 'odd-one-out' experiments by Tantam et al. (1989). Only the task was reversed: instead of selecting the odd one out, the subjects were asked to select the 2 photographs of faces (out of 3) that went together. The subjects were 13 high-functioning autistic subjects (age: 8;2-16;4 yrs), 13 low-functioning autistic subjects (age: 10;2-17;6), 13 HF controls with severe speech and language disorders, and 13 LF mentally retarded controls. In the first task, there were no differences between autistic subjects and their controls: all subjects preferred categorising on identity over type of wig. In a task where faces could be categorised on the basis of identity or expression, the HF autistic subjects, unlike their controls, preferred categorising on identity. LF autistic subjects showed no preference at all. In a cross-modal task, both autistic groups made more errors when vocal expressions of emotions had to be matched to corresponding facial expressions. The authors concluded that these findings support the theory of a specific deficit of emotion recognition in autistic people. Despite the fact that intelligent autistic individuals may have a rudimentary comprehension of the meaning of simple emotional expressions, they seem to attach little significance to them. The deficit in the mentally retarded autistic children is even more severe in that they seem to have no understanding of emotional expressions at all.

Davies, Bishop, Manstead, and Tantam (1994) also examined face perception in both high- and low-ability autistic subjects. The 10 high-ability autistic subjects (mean age: 14.92 yrs) and 10 low-ability autistic subjects (mean age: 13.91 yrs) had control groups that were comparable in age, nonverbal IQ, and verbal IQ. The study consisted of 2 experiments. The first experiment was a concept learning task. Similar to the stimuli in the 'odd-one-out' and 'go-together' tasks, the face stimuli differed on different dimensions: identity, expression, and incidental features. In a control condition, non-facial stimuli differed on shape, colour, and border. The task was to match 2 (out of 6) stimuli for every concept (dimension). The high-ability autistic subjects performed worse than their controls on all tests, while the low-ability autistic subjects performed comparably to their controls on every test. Thus, no evidence for an expression or face specific impairment was found in this experiment. However, the task required the subjects to classify the same stimuli according to different concepts, and the possible executive function deficits in autistic subjects might, thus, have been significantly influencing their performance. Therefore, a second experiment was conducted. Nine high-ability autistic subjects (mean age: 14.35 yrs) and 10 low-ability autistic subjects (mean age: 13.72 yrs) were compared to 11 high-ability and 20 low-ability controls who were comparable in age, verbal IQ, and nonverbal IQ. The experiment consisted of matching tasks: facial identity match with orientation change, facial identity match with expression change, facial expression match with identity change, and symbol pattern match with symbol location change. The results were similar to those in experiment 1: the high-ability autistic subjects were worse than their controls on all tasks, and the low-ability autistic subjects did not differ from their controls on any task. IQ scores were correlated with task performance in the low-ability autistic group. The results are interpreted as a general perceptual deficit in high-ability autistic subjects. The authors reasoned that this perceptual deficit may impair configural processing of faces, and that this affects both identity and expression recognition. However, the lack of an emotion-specific deficit in this experiment may also be due to the methodology, which does not require interpreting the meaning of the facial expressions. This allows the autistic subjects to use different processing strategies that are more perceptually based.

1.2.2. Conclusions

The early face perception experiments with autistic subjects started from the viewpoint that a socio-affective deficit is central to the autistic syndrome. The experiments conducted by Hobson and colleagues, in particular, were aimed at examining this suggestion and seemed to confirm it: performances on cross-modal emotion recognition tasks were worse for autistic subjects than for their controls, autistic subjects preferred sorting faces by type of hat over sorting on expression, and their response pattern was different from controls on masking conditions of facial expressions. But even performances on tasks which were not primarily emotion-based were interpreted as resulting from an affective deficit. Relatively good performance on tasks with inverted faces and a deviant pattern of attention in face recognition tasks were thought to stem from impaired processing of the socio-affective information of the face. It was argued that autistic subjects perceive the face as a complex visual pattern and not as a social stimulus.

Later studies, however, failed to find strong evidence for such an emotion-specific deficit. Some studies still found small group differences, but only compared to controls matched on nonverbal IQ. Moreover, impairments on other aspects of face perception, such as identity matching, seemed to be affected in autistic subjects as well. The question became one of specificity. First, is the emotion deficit specific for the autistic syndrome, and second, is the autistic deficit emotion-specific, face-specific, or is there a more general visual perception deficit?

The answers are not unequivocal. The results depend on several factors, such as selection criteria for control groups and the autistic subjects' level of ability. For example, mental retardation in autistic subjects may camouflage specific impairments in the autistic population. Despite the sometimes confusing results, however, a coherent picture is slowly emerging. Even though the emotion deficit has not turned out to be as specific and central as was previously thought, expression recognition is still considered to be the most affected aspect of face processing. Identity recognition appears to be less impaired, but it is still more impaired than recognition of nonsocial stimuli such as objects. This impairment seems specific for remembering and recognising unfamiliar faces, leaving recognition of familiar faces intact. The autistic subjects seem to use different processing strategies. They prefer sorting and categorising faces on the basis of salient perceptual cues, such as the type of hat someone is wearing, over sorting by expression or identity. They will also use these strategies in other tasks that offer the opportunity to use perceptually-based strategies, for example in matching tasks. Furthermore, they seem to rely more than controls on verbal strategies in expression recognition tasks, in all likelihood to compensate for their deficit in emotion recognition.

1.3. THEORETICAL ASPECTS OF FACE PROCESSING

The studies on the face perception of autistic subjects raise some important questions about the processes involved. For example, is it possible that recognition of facial expression is selectively impaired while other aspects of face processing, such as recognition of familiar faces, are still intact? Is it possible to associate poor performance on certain face perception tasks with deficits in particular face processing stages? Are there impairments in the encoding of faces into memory or in the retrieval of mental representations? Are the impairments quantitative, as a result of slow or impaired development, or do autistic subjects use qualitatively different face processing strategies?

To place these questions in the context of a theoretical background, methods and models from normal face processing studies are presented in the following section. Four issues are discussed that are considered relevant for understanding the performances of autistic subjects on face perception tasks. First, a functional model of face processing is presented that describes the separate processing stages and their connections. This model may be helpful in answering questions concerning selective impairments. Next, experiments that investigated the nature of mental representations of faces are reviewed, including the implications of the results for recent theories. The third issue concerns the perception of facial expressions, which is particularly relevant for the study of autism. Lastly, the development of face processing abilities in infants and children is briefly reviewed.

1.3.1. The functional architecture of face perception

The findings of the studies of autistic subjects' face perception indicate that some but not all aspects of face processing are impaired in this population. Recognition of expressions and unfamiliar faces is impaired, while familiar face recognition and the ability to lip-read seem to be intact. This pattern of findings suggests that face processing consists of several independent subprocesses that can be selectively damaged.

Evidence for this suggestion is provided by studies on patients with selective brain damage, for instance, in prosopagnosia. Prosopagnosia patients are unable to recognise the faces of familiar people (Bodamer, 1947). Although most of these patients suffer other function impairments as well, there have been some reports of pure prosopagnosia (Pallis, 1955; Bruyer et al., 1983; de Renzi, 1986), where only familiar face recognition is impaired and object and word recognition is still intact. They can recognise a person by cues other than the face, such as the voice or gait. They can distinguish a normal face pattern from a scrambled face (Blanc-Garin, 1984), which indicates that they perceive a face as a face. Furthermore, they are able to identify the separate facial features. Some prosopagnosia patients can still recognise facial expressions (Hécaen & Angelergues, 1962; Shuttleworth, Syring & Allen, 1982; Bruyer et al., 1983). The opposite pattern is also found: patients who recognise familiar faces but are unable to interpret a facial expression (Bornstein, 1963; Kurucz & Feldmar, 1979; Kurucz, Feldmar & Werner, 1979). Such a 'double dissociation' between impairments is seen as strong support for distinctive processing mechanisms. It has not only been found for recognition of familiar faces and expressions, but also for lip-reading and expression recognition (Campbell, Landis & Regard, 1986), and for familiar and unfamiliar face recognition (Malone, Morris, Kay & Levin, 1982).

Evidence for separable functional components in face processing has also been found in laboratory experiments with normal adults. For example, familiarity of faces has no influence on the recognition performance of facial expressions (Young, McWeeny, Hay & Ellis, 1986; Bruce, 1986), and Bruce (1979) found no correlation between performance on familiar and unfamiliar face recognition tasks.

These findings from studies of normal subjects and of the effects of brain injuries have led to the development of several functional models of face processing (e.g., Hay & Young, 1982; Rhodes, 1985; Ellis, 1986), which describe the functional components in face perception and their interrelations. The model proposed by Bruce and Young (1986) has become the most influential (Fig. 1.1).

The model is most explicit about the recognition of familiar faces, which is described as a serial process involving several successive stages. It proceeds independently and parallel to other face processes (directed visual processing, lip-reading, and expression analysis). Before these processes are split, a face is first recognised as a face in the structural encoding stage (however, there is no empirical evidence for this stage, and, therefore, it has been excluded from subsequent models). Subsequently, the structural information of the face is processed in the separate processing modules. Recognition of a familiar face involves several successive stages. First, the face is recognised as familiar in the 'face recognition units'. At this stage, the subject is aware that the face is familiar, but does not know whose face it is. This recognition of identity takes place in the next stage, the 'person identity nodes'. In the final stage, the name of the familiar person is generated. Other information that may be of interest for face recognition but that is not explicitly reflected in the model, such as knowledge stored in long-term memory, is placed in the 'cognitive system'. Types of input that activate person identity nodes via means other than the face, such as the voice and body movements, are not included in the model.

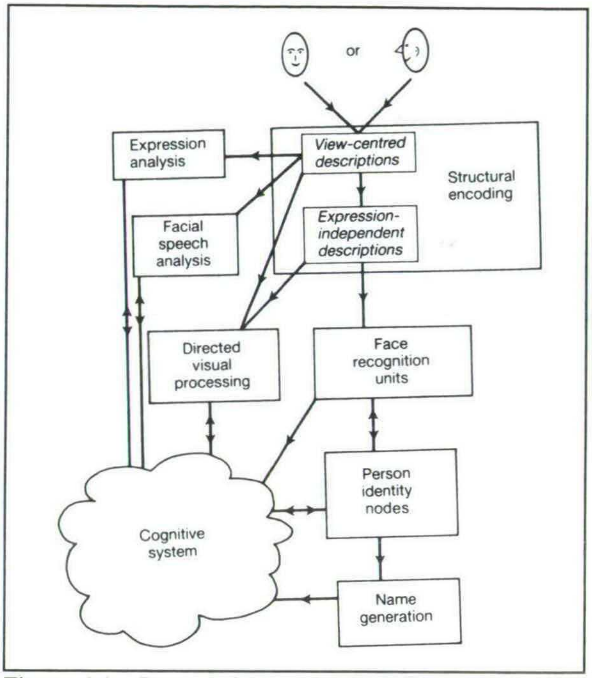

Figure 1.1.: Bruce and Young's (1986) functional model for face recognition.

The face processing model was further specified in a computer simulation (Burton, Bruce & Johnston, 1990; Burton et al., 1991). The system was thought of as an interactive activation system consisting of separate modules (Fodor, 1983), but with bidirectional connections within and between these modules. Recognition of individual faces was simulated by changing activation levels of identity nodes, which correspond to the faces stored in memory and their connections. The authors used the model to simulate a number of phenomena in face perception, such as repetition priming and associative priming. Repetition priming concerns the facillatory effect of prior exposure of a target face in a familiarity decision task and can be understood in the neural model as a result of higher activation strengths between nodes within a module. The model explains associative priming, the facilitory effect of prior exposure of an associated face (e.g., the face of Laurel facilitates the recognition of Hardy), as higher activity at the nodes themselves (Young & de Haan, 1988; Young & Ellis, 1989; Burton et al., 1990). The model also gives an account of covert recognition in prosopagnosia patients (Burton et al., 1991). In covert recognition, patients are unable to recognise a familiar faces consciously, but when tested indirectly by skin conduction (Bauer, 1984; Tranel & Damasio, 1985), evoked potentials (Renault et al., 1989), eye movements (Rizzo, Hurtig & Damasio, 1987), face-name learning (Bruyer et al., 1983; Young & de Haan, 1988; de Haan, Young & Newcombe, 1987a, 1987b; Sergent & Poncet, 1990) or matching, priming, and interference experiments (de Haan et al., 1987b; Young, Hellawel & de Haan, 1988), they react differently to familiar and unfamiliar faces. The model assumes a deficit in the person identity nodes that are not activated enough to reach the threshold for conscious recognition. Likewise, other behavioral data of prosopagnosic patients can be replicated by the model, by 'damaging' parts of the system.

The findings of studies of the face perception of autistic subjects seem to suggest that two modules in the Bruce & Young model are flawed: expression analysis and the directed visual processing that is involved in recognising unfamiliar faces. The model, however, which focuses primarily on familiar face recognition processes, is not very informative about *how* these modules might be affected. It cannot make clear why and how expression analysis is more damaged than directed visual processing, nor can it explain why the impairments are only found in certain types of tasks and not in others. Furthermore, does the fact that processes behave as independent modules automatically mean that impairments found in two or more modules are caused by as many deficits, or can one underlying deficit impair more modules? Perhaps the deficit is not in the modules for expression analysis and directed visual processing, but in the structural encoding module. If this module is damaged, it will have consequences for all successive processing stages. But even then, it cannot explain why expression and unfamiliar face recognition are affected by this deficit, and other modules, which also depend on output of the structural encoding module, are not. Clearly, to understand what goes wrong in autistic subjects' perception of faces, it is not sufficient to locate flaws in the functional architecture of a face processing model.

1.3.2. Mental representations of faces

The findings of the face perception studies not only suggest *quantitative* differences between autistic and control subjects, such as poor recognition of expressions and unfamiliar faces, but also some *qualitative* differences. For example, autistic children pay more attention to different parts of the face than control children. The relative good performance on tasks with inverted faces can also be interpreted as resulting from a different face processing style. There have been numerous studies of normal adults' and children's ability to deal with inverted faces, and the large majority of these studies show that there is a sharp decrease in task performance when faces are presented upside-down (see Valentine, 1988, for a review). This decrease has been found in many different paradigms, and is much larger for faces than for most other stimuli. According to Diamond and Carey (1986), three conditions must be met to find a large inversion effect. First, the stimuli must be members of a class that share a configuration; second, identification of the individual members of this class must be on the basis of their 'second-order relational features' (the distinctive relations among the elements of the configuration); third, the subjects must have a significant degree of familiarity with the stimulus class. In the case of face stimuli, these criteria are met, but Diamond and Carey (1986) show that the criteria are also met when dog experts are asked to recognise inverted dogs. The inversion effect of faces is smaller for children because they are not yet as experienced with faces and thus have little expertise. The relevance of the configuration for recognising faces is also supported by the finding that the inner features of a face become relatively more important when the face becomes more familiar (Ellis, Shepherd & Davies, 1979; Endo, Takahashi & Maruyama, 1984; Young, Hay, McWeeny, Flude & Ellis, 1985).

Inversion is not the only experimental manipulation that shows the importance of configuration in face processing. It is also evident in the so-called 'face superiority effect' (Homa, Haver & Schwartz, 1976; van Santen & Jonides, 1978; Mermelstein, Banks & Prinzmetal, 1979). Recognition of the inner features of the face is better when these features have to be remembered in the context of a normal intact face than in a 'scrambled face'. A scrambled face is an artificial stimulus consisting of a facial outline in which the spatial positions of the inner features are changed. Mermelstein et al. (1979) showed that the opposite effect, a face inferiority effect, is found when a visual search for a target feature in a context stimulus is required. They proposed that the crucial factor for finding either a face superiority or inferiority effect is the presence or absence of a memory component for the context stimulus in the task. If the task requires remembering the facial context, a face superiority effect will be found; if the task is a perceptual search of the face stimulus, a face inferiority effect is found.

The memory component is also involved in another paradigm in which facial features have to be recognised in facial and nonfacial contexts. Tanaka and Farah (1993) asked subjects to learn names for faces and scrambled faces. After this learning phase, the facial features were shown in their original context (normal or scrambled face) or in isolation, together with a distracter that only differed on the relevant feature. They found that subjects were more accurate in recognising the facial features in the original context of the normal face than in isolation, while scrambled faces were not facilitating relative to isolated presentation. Tanaka and Farah propose that these findings indicate that a face is encoded in memory as a whole, without explicit representations of the constituent features. Carey and Diamond (1994) argue, on the basis of developmental data, that this holistic encoding is not identical to the configural encoding that is disrupted in inversion tasks. They presented a task to adults and children that was developed by Young, Hellawell and Hay (1987), in which the upper half of a composite face had to be recognised in upright and inverted orientation of the stimuli. When the upper and bottom parts of the composite faces are aligned, and thus a new facial Gestalt is created, recognition is more difficult than when these parts are not aligned, but only in the upright presentation mode. This composite effect was found to be independent of age, although even in this task, the effect of inversion on recognition was larger for adults than for children. This suggests that the holistic representation of faces is present from childhood, but the more subtle differences in second-order relational features become more important for recognition with growing expertise.

These findings contribute to the development of theories concerning the mental representations of faces in memory. The results of holistic tasks indicate that faces are encoded as wholes, while the inversion tasks suggest that the configurations of these facial wholes are crucial for remembering individual faces. Most theorists assume a multidimensional representational space in which faces are represented on the basis of some discriminating dimensions, but they disagree on what defines the nature of the internal structure of this mental space. Goldstein and Chance (1980) suggest that as a result of daily exposure to upright, detailed visual images of faces in our particular environments, people develop a 'face schema', a prototypical representation of a face. This face schema serves as a reference that facilitates recognition of newly encountered faces. As a result of experience, the schema gets more specified, but also less flexible for unusual transformations. This explains the increasing effect of inversion with age, but also the superior discrimination of own-race faces, because these are usually encountered more frequently in life than other-race faces. The model also predicts a race x inversion interaction, which has indeed been found: young children recognise other-race faces as accurately as own-race faces (Goldstein & Chance, 1980; Chance, Turner & Goldstein, 1982). A study by Bruce, Doyle, Dench, and Burton (1991) with identikit faces gives some indication of how a face schema might develop. They found that subjects extracted a prototypical representation from exemplars that had a slightly different configuration. In a forced choice recognition task, prototypical faces were 'recognised' more frequently than the exemplars, even when the prototypes were never actually shown.

The idea of a prototype reference for newly encountered faces was the basis of the face representation models of both Valentine (1986; Valentine and

Bruce, 1986b, 1986c) and Rhodes and colleagues (Rhodes, Brennan & Carey, 1987; Rhodes, Tan, Brake & Taylor, 1989; Rhodes & Mclean, 1990). The essential hypothesis in the model developed by Rhodes et al. (1987) is that the distinctiveness of a face is coded in the mental representation of a face. Distinctiveness is defined as the metric deviation from a spatial norm (the prototype representation). This model can explain why a distinctive face is recognised more quickly than a typical face (Going & Read, 1974; Cohen & Carr, 1975; Light et al., 1979; Bartlett et al., 1984; Valentine & Bruce, 1986a, 1986b). They claim that the caricature effect is another argument for the norm-based coding model. This effect concerns the finding that caricatures of familiar faces are recognised more quickly than their veridical drawings (Rhodes et al., 1987). This finding was replicated with photographic quality caricatures (Benson & Perrett, 1991). It is not clear whether there also is a caricature effect for unfamiliar faces: no effect was found with 'goodness of likeness' judgements (Rhodes et al., 1987) and in an old/new recognition test (Rhodes & Moody, 1990), but Mauro & Kubovy (1992) found a caricature effect with identikit caricatures. The caricature advantage is not specific to faces: Rhodes and McLean (1990) also found a caricature advantage when testing bird experts for birds from a highly homogeneous class, suggesting that the caricature effect becomes stronger with expertise. However, this relation with expertise does not seem consistent with the finding that the caricature effect is equally large for upright and inverted faces (Rhodes & Tremewan, 1994). Another problem in caricature studies is determining what should be taken as the reference face. Benson, Perrett, and Davis (1992) argue that it is not appropriate to suppose one prototype face to be the reference for all individual faces. In order to create an effective caricature of an individual face, the reference face ("base face") should be a typical face of the same race, age, and sex as the exemplar. This issue is of relevance for the prototype models, but is as yet not accounted for.

The prototype model proposed by Valentine and Bruce (1986a, 1986b; Valentine, 1988) is very similar to that of Rhodes and her colleagues. The main difference is that in Valentine's model, the dimensions of deviation can be any properties (spatial and otherwise) to distinguish faces, in contrast to the spatial norm in Rhodes' model. In later papers, Valentine (1991a, 1991b; Valentine & Endo, 1992) proposed that an exemplar-based coding model can account for the effects of inversion, distinctiveness, and race at least as well as a norm-based coding model. In an exemplar-based model, proximity of the representations in the multidimensional space determines how well a face is discriminated from other faces. However, an exemplar-based model will probably encounter even more difficulties than a norm-based model in explaining caricature effects.

The prototype models have been developed to explain how people encode newly encountered, unfamiliar faces. They are probably less appropriate to account for the processes involved in familiar face recognition. Bruce and Young (1986) cite evidence that shows that familiar faces are processed differently from unfamiliar faces. It is not clear how representations change when faces become more familiar. A recent study by Beale and Keil (1995) might be of interest here. Analogous to a study concerning categorical perception of expressions (Etcoff and Magee, 1992), Beale and Keil created continua of morphed faces between individual exemplars of familiar faces. These stimuli were presented in three tasks: categorisation, discrimination, and rating of 'better likeness'. In the discrimination task, face-pairs that crossed an apparent category boundary were discriminated more accurately than within-category faces, even though the physical distance was the same for every face-pair. Moreover, this categorisation effect was stronger when the faces were more familiar. The authors suggest that, through experience with particular faces, a prototypical representation of that face may develop with clear category boundaries. While the norm-based coding models account for the effects of distinctiveness, race, and inversion, the categorical effect of familiar faces seems informative of how representations of individual faces change with experience. Furthermore, it may help understand how the processing of familiar faces becomes qualitatively different from unfamiliar face processing (Bruce & Young, 1986). Deviation from a norm may be of more importance when the faces are unfamiliar, whereas familiar faces may be represented as more or less independent instances with clear category boundaries. It is probably also more appropriate to consider the caricature effect as a phenomenon that is related to the specific processes of familiar face recognition.

1.3.3. Perception of facial expressions

Bruce and Young's model (1986) assumes that the recognition of facial expressions is a process independent of other face perception processes. The findings in studies with autistic subjects indicate that these expression recognition processes are impaired most in face perception. However, there are only a few studies that address the face processing mechanisms involved in the perception of emotional expressions.

An important paper in this respect is a study by Etcoff and Magee (1992). They argue that, from an evolutionary point of view, it might be beneficial to have an innate perceptual mechanism for recognising the expressions corresponding to the six basic emotions (Ekman & Friesen, 1971). They cite several studies that seem consistent with this hypothesis: single-cell recordings that revealed cells selectively responsive to expressions (Hasselmo, Rolls & Baylis, 1989; Perrett et al., 1984), brain injuries that selectively impair expression recognition (Bruyer et al., 1983; Campbell, Landis & Regard, 1986; Etcoff, 1984), electrical stimulation of brain areas that selectively impair expression recognition (Fried et al., 1982), and early recognition of expressions in infants (Meltzoff & Moore, 1977; Caron, Caron & Meyers, 1982; Walker-Andrews, 1986). If such a mechanism exists, then it is expected that the basic expressions differ qualitatively, rather than varying continuously along an expression continuum. The paradigm they used to investigate this was inspired by methods in categorical perception studies of speech and colour. They created morphed faces that differed with equal physical steps along a continuum from one expression to another and presented these in an identification and a discrimination task. They found that for most expressions (except surprise), between-category face-pairs were better discriminated than within-category pairs. They interpreted this as evidence for the categorical perception of expressions. However, the fact that the expressions were perceived categorically does not necessarily imply an innately tuned perceptual mechanism for these expressions. The finding that categorical perception is also found for recognition of familiar faces (Beale & Keil, 1995) casts doubt on this suggestion. The similarity with the results of familiar face perception suggests that expressions are not perceived categorically because of an specialised expression recognition mechanism, but because expressions have become familiar through experience. However, even though the findings of Beale and Keil make such a specialised mechanism somewhat unlikely, it is still possible that different perception mechanisms yield similar results in this particular paradigm.

One other suggestion resulting from the Etcoff and Magee study is that expressions are perceived as configurations, as the morphing procedure concerns changing the face as a whole and not on the basis of the individual features. A study conducted by Wallbott and Ricci-Bitti (1993) further confirms this suggestion. They presented photographs of faces expressing single muscular movements, so-called action units (Ekman & Friesen, 1978) related to certain facial expressions, in an otherwise neutral face or in combination with other action units. They found that the emotional meaning of the separate action units changed within the context of other action units, which strongly suggests configural encoding of expressions. The configural processing of expressions is also suggested by the so-called 'Margaret Thatcher illusion' (Thompson, 1980), the effect that the grotesque and gruesome expression of a face in which the eyes and mouth are inverted, is not perceived when it is presented upside-down. Although different explanations for this phenomenon are possible (Parks, Coss & Coss, 1985; Rock, 1988), it seems evident that disturbing the perception of the configuration by inversion contributes greatly to the effect. The finding of Parks et al. (1985) that pleasantness ratings of an upright or inverting mouth are influenced by the relative position of the eyes, supports this suggestion.

In the present thesis, Etcoff and Magee's paradigm (1992) will be further explored and used to study expression recognition in children and autistic subjects.

1.3.4. Development of face perception

Autism is a developmental disorder. Therefore, the impairments found in autistic individuals may result from a developmental delay. This would mean that their perception of faces may not be qualitatively different from that of normal people, but only worse. However, some findings from face perception tasks suggest that autistic individuals perform qualitatively differently from young children, suggesting that the impairments are not just the result of slow development. In this section, a brief overview of face processing abilities in infants and children is given to put the results of autistic subjects in a developmental context.

Face perception in infants. One issue in the face perception literature is whether faces are "special" for the human information processing system, the claim that there is a specialised mechanism for face processing (e.g., Hay & Young, 1982; Diamond & Carey, 1986). A strong argument for such an innate mechanism is the finding that newborn infants prefer looking at a moving schematic face over a moving scrambled face (Goren et al., 1975; Maurer & Young, 1983; Johnson et al., 1992). However, this preference disappears within the first month of life. Morton and Johnson (1991) account for this phenomenon by assuming two biologically provided mechanisms, 'CONSPEC' and 'CONLERN'. CONSPEC is the subcortical mechanism that directs attention to objects of biological significance, such as members of the species. Within the first month of life, the relative significance of this mechanism declines, and a cortical system (CONLERN) for the recognition of the individual members of a species becomes more important. Discrimination and habituation studies show that the infant recognises the mother's face within a few days (Bushnell et al., 1989). By the age of six or seven months, infants can discriminate faces of different sex and age (Fagan, 1972) and discriminate different faces of the same sex, as well as different views of the same face (Fagan, 1976).

It is less clear how well infants are able to recognise facial expressions. five-month-old infants are unable to respond differentially to photographs of faces with different facial expressions (Spitz & Wolf, 1946; Ahrens, 1954), but Weeks and Hobson (1987) argue that this may be due to the artificial test situation. Discrimination of different facial expressions in infants was found in several other studies (LaBarbera et al., 1976; Nelson et al., 1979; Caron et al., 1982; Field et al., 1982). The behaviour of one-year-old children who are confronted with a visual cliff is influenced by the emotional expression of their mothers (Klinnert, Campos, Sorce, Emde & Svejda, 1982). At 2-and-a-half, children were found to be able to indicate which of three photographs depicted a particular expression (Izard, 1971), which suggests that at least some basic understanding of expression is present at that age.

Face perception in children. The first study on children's expression recognition was carried out by Gates (1923), who found a gradual increase in the ability to interpret facial expressions, a conclusion that was confirmed in a paper by Charlesworth and Kreutzer (1973), who reviewed the expression recognition studies of the fifty years that followed. The gradual increase of the ability to recognise expressions was further suggested in studies by Izard (1971), Camras (1980), and Walden and Field (1982). However, studies by Bullock and Russell (1984, 1985) and Markham and Adams (1992) suggest that this ability might have been underestimated by these previous studies.

Bullock and Russell studied the capacity of adults and 2- to 5-year-old children to match emotion-descriptive words to photographs of facial expressions (Bullock & Russell, 1984) and categorise expressions on the basis of similarity (Bullock & Russell, 1985). The authors argued that expressions are processed both categorically and dimensionally in all age groups, with arousal level and pleasure-displeasure as the most dominant dimensions. Category boundaries were more fuzzy than distinct, allowing the same expression to fall into different, overlapping categories. The difference between adults and children was that the categories for children were much broader than for adults, and the younger the children were, the more broader the expression categories.

The recognition of facial expressions by children at ages 4, 6, and 8 years of age, was examined by Markham and Adams (1992). They administered 4 types of tasks to the children: a situation discrimination task in which the appropriate facial expression to an emotion-inducing situation has to be chosen; a matching task that requires matching a target facial expression with one of a set of expressions; a forced-choice labelling task in which the appropriate label has to be chosen for a target facial expression; and a free labelling task, where the children are asked to generate a verbal label to describe a facial expression. They found that 6- and 8-year-old children performed better on these tasks than the 4-year-olds, but there was no interaction between task, age, and emotion. The free labelling task was the most difficult for all age groups. Compared to the 6-year-olds, 8-year-old children were better only on recognising surprise, which was also the broadest expression category in Bullock & Russell's study (1985), and the only expression that was not perceived categorically in the study by Etcoff and Magee (1992). The authors suggest that at the age of 6, an asymptote for expression recognition may have been reached.

Despite the fact that expressions seem to be recognised quite accurately at the age of six, the encoding of unfamiliar faces is still very poor at this age. It is now well established that performance on unfamiliar face recognition tests improves markedly as children grow older (e.g., Goldstein & Chance, 1964; Kagan & Klein, 1973; Carey & Diamond, 1977; Diamond & Carey, 1977; Blaney & Winograd, 1978; Carey, Diamond & Woods, 1980; Flin, 1980; see Chung & Thomson, 1995, for a review). The most important improvement seems to be that children become able to process larger amounts of information. For example, the set size of faces that can be remembered increases from infancy to puberty (Benton & van Allen, 1973; Carey et al., 1980). Furthermore, 7-year-old children fail to take advantage of exposure times longer than

2 seconds, whereas recognition performance of 10-year-old children improves when inspection time is prolonged (Ellis & Flin, 1990). According to Chung and Thomson (1995), this development in encoding ability occurs because the efficiency of both featural and configural encoding increases with age. The hypothesis that the prototypical representation of the norm (Rhodes et al., 1987) becomes more specified with age (Carey and Diamond, 1994) seems to be a further specification of this idea. Several findings are in line with this theory. Effects of distinctiveness and inversion are both considered to result from a fuller specification of the norm, and these predictions have been empirically confirmed. Young children, in contrast to adults, recognise distinctive faces and typical faces equally well (Ellis, Wallace & Ellis, submitted, cited in H.D. Ellis, 1992), and the inversion effect is smaller for children than for adults (Carey, 1981; Flin, 1983; Carey & Diamond, 1994). The increase of the inversion effect with age results from a relatively better developed ability to encode upright faces than inverted faces, since young children are not different from older children in recognising inverted photographs of faces (Carey & Diamond, 1977; Carey et al., 1980). Therefore, the increasing encoding ability seems to be specific for faces, and this is consistent with the suggestion that a face-specific prototype representation is developed in childhood.

When this prototype representation is not yet fully developed, children seem to rely mainly on overall similarity of faces in recognition and categorisation studies (Smith & Kemler, 1978; Kemler, 1983; Flin, 1985a). Kemler (1983) found that, in a face categorisation task, young children categorised faces on overall similarity, whereas older children were more able to use critical attributes for categorisation. Kemler argues, on the basis of these findings, that normal development reflects a shift from a holistic processing mode toward more frequent use of the analytic mode associated with differentiation. Carey and Diamond (1994) came to a similar conclusion when they found no interaction between age and the composite effect, an effect that these authors believe results from holistic encoding. If holistic encoding is based on overall similarity, it should be less efficient when the face stimuli undergo some sort of transformation between test and recognition. Young children do indeed perform poorly on tasks where photographs of faces change in size, expression, pose, direction of lighting, and paraphernalia (Saltz & Sigel, 1967; Benton & van Allen, 1973; Diamond & Carey, 1977; Ellis, 1990). Changing the environmental context between study and test also disrupts the recognition performance of young children (Markham et al., 1991). Diamond & Carey (1977) found that when photographs of two unfamiliar faces with similar paraphernalia are presented, 6- and 8-year-old children judge them to be the same person. However, when the faces are very dissimilar, the children are not distracted by hats, glasses, etc. (Flin, 1985b).

Recognition of familiar faces does not seem to be very different in young children when compared to adults. For example, paraphernalia do not disrupt recognition of familiar faces (Diamond & Carey, 1977). Furthermore, Ellis, Ellis, and Hosie (1993) found that 5-year-old children, although they were slower, showed the same priming effects for familiar faces as older children. The caricature effect in children is somewhat unclear, but with a highly familiar face, even 6-year-olds seem to recognise a caricature faster than the veridical photograph (Ellis, 1991). Around puberty, the development of face encoding ability comes to a standstill or even falls back to lower performance levels, reaching the adult recognition level only after puberty (Carey et al., 1980; Flin, 1980, 1983). Chung and Thomson (1995) point out, however, that this 'developmental dip' is not a very robust finding. In some studies, it does not reach significance, and the studies are not unanimous about the age at which the dip occurs. Moreover, some studies report merely a levelling in performance rather than an actual decrement. The developmental discontinuity is also not a face-specific phenomenon; it has also been found for other processing abilities, such as recognising voices (Mann et al., 1979), pictures (Flin, 1985a) and tones (Spreen and Gaddes, 1969), and for problem solving capacities (Weir, 1964; Somerville & Wellman, 1979). Although several hypotheses have been put forward to understand this temporary decline (see Chung & Thomson, 1995, for an overview), the hormonal and physical changes associated with puberty seem to be the most serious candidates for an explanation. Diamond, Carey, and Back (1983) found that girls who were actively pubescent performed worse on face recognition tasks than pre- and post-pubescent girls. However, these maturational changes only indirectly affect face processing, and it is not clear how the findings should be interpreted in terms of information processing theories.

1.3.5. Conclusions

In this section, studies and models of normal face processing were discussed to provide a theoretical context for the face perception studies of autistic subjects. First, a model of the functional architecture of face processing was reviewed. This model, based on experimental studies with normal adults and the neuropsychological findings of brain-injured patients, proposes that expression recognition, lip-reading, directed visual processing, and familiar face recognition are independent processes that proceed in parallel. In addition to this functional model, a prototype or norm-based model was described which gives an account of how faces may be encoded and represented in memory. This model seems to be most appropriate for understanding how unfamiliar faces are encoded. Two processing modes, holistic and configural, are basic to the model. The holistic mode is most dominant in childhood and is related to the face superiority and inferiority effects and the composite effect. It concerns the global processing of faces as wholes, with no explicit representations of the constituent parts. Recognition of individual faces is not very efficient in the holistic processing mode, as it is based on overall similarity. During childhood, recognition ability increases as the configural aspects of the face become more important for face encoding. Newly encountered faces are then encoded relative to a norm representation that becomes more completely specified with age. Configural encoding is related to expertise effects, such as inversion, distinctiveness, and race. When a face becomes familiar, the representation seems to change into an individual prototype with clear category boundaries. Categorical perception studies suggest that facial expressions are represented in memory in much the same way as familiar faces, although there might be a specialised mechanism for recognising the configurations corresponding to the basic expressions. With age, the expression categories probably become narrower and more distinct.

The pattern of results for autistic subjects (section 1.2.) suggests that this group's configural encoding processes might be disturbed. The configural information of the face is essential for both unfamiliar face processing and expression recognition, and these are the most impaired face processing abilities in autism. Furthermore, the absence of an inversion effect also suggests that these second-order relational features are not processed normally by autistic subjects.

1.4. RESEARCH QUESTIONS

While in the past most studies on face perception in autistic subjects were concerned with which processing aspects are impaired and which are not, the objective of the present thesis is to place the findings in the context of recent models of face perception. The focus is on the nature of face processing and how selective impairments can emerge in autism.

Three main questions were addressed in the experiments:

1. *Are the impairments in face processing due to one underlying deficit, or are separate modules affected in autism?*
2. *Are facial expressions perceived categorically, and is this ability impaired in autism?*
3. *Are autistic individuals impaired in the configural and holistic processing of faces?*

The first experimental study concerns the first research question and is described in Chapter 2. A clinical task battery, developed by Bruyer and Schweich (1991), was used to study components in the face recognition system of autistic subjects. This task battery is based on the functional model developed by Bruce and Young (1986) and was originally designed to investigate selective face processing impairments in prosopagnosic patients. Because it taps the several modules in the Bruce and Young model, it is considered to be an appropriate test to explore the specificity of the impairments in the autistic population.

The second study (Chapter 3) investigates the categorical perception of facial expressions of normal adults and children in an experiment similar to that of Etcoff and Magee (1992). However, instead of using line-drawings as they did in their study, real photographs were used to create the intermediate stimuli between two prototypical facial expressions. This was done by applying a digital image morphing technique developed by Benson & Perrett (1991). To control for a possible influence of dichotomisation artefacts, a second experiment was carried out using the same stimuli presented upside-down. In addition, goodness ratings of the facial expressions were gathered to explore the internal structure of the emotion categories.

In Chapter 4, the same method is applied to compare the performance of normal adults to that of high-ability autistic adolescents. Face perception studies of autistic subjects show that expression recognition seems to be affected more than other aspects of face processing. The study of categorical perception of expression might indicate how this ability is affected.

The rest of the experiments are related to the third research question. These are discussed in Chapter 5. An inversion and a composite task were used to examine configural and holistic processing of faces in autistic individuals. Certain findings in the face perception literature suggest that autistic subjects are impaired in processing faces as configurations. Evidence for this is suggested by impaired recognition of unfamiliar faces and emotional expressions and by their remarkable performance on inversion tasks. In the first experiment in this chapter, inverted and upright photographs of faces were presented in a forced-choice recognition test. A control condition with shoes was added to determine whether the inversion effect is disproportionally larger for faces than for objects, as has been found in studies with normal adults. In the second experiment, holistic processing was studied using a task with composite faces. The absence of a composite effect would suggest that faces are not processed as configural wholes, which would be consistent with the hypothesis of weak central coherence in autism (Frith, 1989).

Face superiority effects in autistic individuals are studied in Chapter 6, using a memory search task with normal and scrambled face stimuli. Another interesting question addressed in this chapter concerns the possible existence of an 'expression superiority effect'. It is reasoned that if the superiority effect depends on Gestalt-like properties of a stimulus, then remembering facial features in a coherent expression (e.g., happy eyes with a happy mouth) would be superior to a noncoherent expression (e.g., happy eyes with an angry mouth).

In the concluding chapter, the results from the experiments in this thesis are summarised and evaluated. Implications for normal face processing models are discussed, and an attempt is made to give a unitary account of the face processing impairments in autistic subjects. The results are discussed in the framework of theories of autism (see section 1.1.2.). Finally, some suggestions are made for future research into the information processing abilities of autistic subjects.

2. Do autistics have a generalised face processing deficit?[1]

2.1. INTRODUCTION

Faces are an important source of information. We recognise people by their faces, we use lip-reading information when we try to understand speech, and, in social interaction, we pay a great deal of attention to eye direction and facial expressions. Another reason for the growing interest in face processing is the issue of specificity. Several arguments suggest that faces are 'special' for the human information processing system. For example, infants as young as 10 minutes prefer to track a moving schematic face to a scrambled face (Goren, Sarty & Wu, 1975; Maurer & Young, 1983; Morton & Johnson, 1991). The effect of inversion upon face recognition has also been proposed as evidence for a special face processing mechanism, because the decrement in recognition by turning a face upside-down is disproportionately large compared to the inversion of other stimuli (Yin, 1969; Dallett, Wilcox & D'Andrea, 1968; Scapinello & Yarney, 1970; Diamond & Carey, 1986; de Gelder, Teunisse & Bertelson, 1993; for a review, see Valentine, 1988). Another argument that there is a specialised mechanism for face processing is related to a neuropsychological impairment; patients with prosopagnosia are unable to recognise a familiar person by their face (Bruyer, Laterre, Seron, Feyereisen, Strypstein, Pierrard & Rectem, 1983; de Haan, Young & Newcombe, 1992; McNeil & Warrington, 1991). This impairment is specific for faces, as these patients are able to recognise people by other cues, such as voice and gait. The ability to recognise visually presented objects also remains relatively intact in these patients. Animal studies provide a further argument for face specificity: there are cells in the temporal cortex of monkeys that react selectively to faces (Harries & Perrett, 1991; Rolls, 1992; Perrett et al., 1988, 1992).

Although it is still a matter of debate whether these arguments are robust enough to support the notion that faces are indeed special (Hay & Young, 1982; Diamond & Carey, 1986), this focus has led to some very articulate ideas about the processing of faces (Goldstein & Chance, 1981; A.W. Ellis, 1992; Carey, 1992). An important finding is that face processing depends on several modular subprocesses. For example, it has become clear

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[1]Published as: Teunisse, J.P. & de Gelder, B. (1994). Do autistics have a generalized face processing deficit? *International Journal of Neuroscience, 77,* 1-10.

The authors would like to thank the Herman Broerenschool (Rosmalen), Medisch Kinderhuis Apeldoorn, Kinderhuis Reek, School voor VSO de Ortolaan (Heythuysen), Basisschool de Borne (Tilburg), Michael Scholengemeenschap (Tilburg) and the Norbertus MAVO (Tilburg) for their cooperation. Parts of this study have been presented at the International Conference on Face Processing, September 21st-23rd 1993, University of Wales College of Cardiff, U.K.

that there are different forms of prosopagnosia, depending on what subprocess is deficient (de Renzi, 1986; Damasio, Tranel & Damasio, 1990; de Haan et al., 1992; de Haan, 1989). Although all prosopagnosic patients fail at overt face recognition tasks, data from skin conductance measurements (Bauer, 1984; Tranel & Damasio, 1987), eye movement scan-paths (Rizzo, Hurtig & Damasio, 1987; Renault, Signoret, DeBruille, Breton, & Bolgertet, 1989), visual evoked potentials (Renault et al., 1989) and covert recognition tasks (de Haan et al., 1992) show that some subprocesses can still be intact.

To reach a detailed description of the exact nature of a particular prosopagnosic deficit, a model is needed that incorporates these different subprocesses. The model that is most widely put forward in this context is that of Bruce and Young (1986). In this functional model, inspired in part by word processing models, various aspects of face processing are represented. According to the model, the different functions of face processing (expression analysis, facial speech analysis, directed visual processing and recognition of familiar faces) are independent processes. This means, for example, that an impairment in facial speech analysis (lip-reading) has no consequences for the analysis of expression or the recognition of a familiar face, as indeed observed in de Gelder, Vroomen and van der Heide (1991). Only the stages that are involved in recognising familiar faces are specified in the model. In the first stage, a structural code of the image is derived (the face is identified as a face). This code is matched with codes in the face recognition units (the face is recognised as familiar). After this, the semantic information of the person is accessed (the identity of the face is recognised). Finally, the name of the person is generated. An impairment in one of the early stages in this pathway has consequences for the later stages; according to the model, it is not possible to remember the name of a face but not to remember who the person is.

On the basis of this model, Bruyer and Schweich (1991) developed a clinical task battery to investigate face processing by prosopagnosia patients. This battery consists of 6 basic tests tapping the several stages in the Bruce and Young model. When a basic test suggests a specific impairment, subtests for that stage provide an opportunity to look at the disorder in more detail. There are 13 optional subtests. They tested 72 normal subjects varying in age, sex and education with the battery. The performances of these subjects became the standard for evaluating the performances of prosopagnosia patients; a given score on a test was considered defective if it fell below the lowest score of the normals. One patient (PC) was described who appeared to have very selective impairments. With the help of the task battery, it was possible to locate the deficiencies of PC in the architecture of the functional model.

Bruyer and Schweich (1991) suggested that the task battery can be used not only to investigate confirmed or suspected prosopagnosia, but that it can also be employed to explore other kinds of person recognition deficits. In this perspective, it is interesting to use the battery on a different clinical population. Subjects with autism have problems in the recognition of facial expressions (Hobson, Ouston & Lee, 1988; Weeks & Hobson, 1987). It is questionable whether this deficit is specific to facial expression or if other stages in the face processing system are also impaired. Several studies suggest that autistic children have difficulties in remembering (de Gelder, Vroomen & van der Heide, 1991; Boucher & Lewis, 1992) and matching (Tantam, Monagham, Nicholson & Stirling, 1989) new faces, and that they are less sensitive to inversion of photographs in a face recognition task (Langdell, 1978; Hobson et al., 1988; Tantam et al., 1989). On the other hand, lip-reading seems to be unimpaired in autistics, although they make less use of this visual information than normal children while listening to speech (de Gelder et al., 1991). The task battery can help to clarify which face processing stages are affected in people with autism and which are not.

Autism is a developmental disorder. Perhaps their face recognition system is not qualitatively different from that of normals but only slower in its development. In that case, their performance on face recognition tasks would be similar to those of children. Recent evidence suggests that children are also much worse than adults in recognising faces (Carey, 1981, 1992; H.D. Ellis, 1992). Especially when the faces have undergone some sort of transformation (age, expression) children find it very difficult to recognise a face (Carey, 1992). They are easily distracted by clothes (Diamond & Carey, 1977), although this difference is reduced when the faces are very dissimilar (Flin, 1980) or familiar (Diamond & Carey, 1977). A change in environmental context between study and test also confuses the child (Markham, Ellis & Ellis, 1991). Between the ages of 5 and 10 the ability to recognise people gradually improves (Feinman & Entwistle, 1976). Surprisingly, between the ages of 10 and 12 this improvement comes to a halt, sometimes followed by a decline in performance, to reach the adult level only after puberty (Carey, Diamond & Woods, 1980; Flin, 1980). The reason for this developmental dip is not known. Carey (1981) suggests that in this period the children shift to a different encoding strategy for faces going from piecemeal to configurational encoding. Another possibility is that the dip is a reaction to hormonal changes in puberty (Diamond, Carey & Back, 1983). The dip is not limited to face recognition; it is also found in the recognition of voices (Mann, Diamond & Carey, 1979), pictures (Flin, 1980) and tones (Spreen & Gaddes, 1969).

In this paper, the task battery for face recognition (Bruyer & Schweich, 1991) was used to study two issues on face processing in autistics. In the first place, an answer is sought to the question whether the face deficit is localised in specific subdomains of processing or whether it extends over the whole face processing system. Moreover, the impact of developmental factors is investigated by administering the battery to children. In order to examine the developmental dip, the children are split into two age groups: a pre-dip group (7-10 years old) and a post-dip group (12-16 years old). Both the scores of the autistic subjects and the normal children are compared to the adult group. If the pattern of scores between the autistic subjects and the children is different, then the face processing deficit of autistics is not just the result of slow development, but reflects a qualitative difference in their face processing system.

2.2. EXPERIMENT: THE CLINICAL TEST BATTERY FOR FACE PERCEPTION

2.2.1. Method

Subjects

The 20 autistic subjects (19 males, 1 female) varied in age from 7 to 34 years. This large range made it possible to get an impression of developmental changes in autistics. There were 5 subjects between 7 and 11 years old, 11 subjects between 12 and 16 years old, and 4 subjects between 19 and 34 years old. They had been diagnosed according to DSM-III-R criteria (1987) as autistic.

There were 3 control groups: a ‘pre-dip’ and a ‘post-dip’ group (before and after the developmental dip in face recognition (Carey et al., 1980; Flin, 1980), and an adult group. The pre-dip group consisted of 32 children (2 females) with ages varying from 7 to 10 years old, with 4 left-handed children. The post-dip group (all male) varied in age from 12 to 17 years. Of the 29 subjects in this group, 6 were left-handed.

Thirty normal adult university students (12 males, 18 females), varying in age from 19 to 34 years (mean = 25 years), were tested to make a comparison with the results of the highly-educated, 20-40 age group of Bruyer and Schweich (1991). Four female subjects were left-handed; all male subjects were right-handed.

Nonverbal intelligence of the autistic and the two children groups was measured with the Raven SPM. The raw scores are given in Table 2.1, together with the age characteristics. The scores of the autistic subjects were lower than the scores of the post-dip group ($p = 0.014$) and somewhat higher than the scores of the pre-dip group ($p = 0.034$).

THE CLINICAL TEST BATTERY FOR FACE PERCEPTION

The neuropsychological test battery constructed by Bruyer and Schweich (1991) consists of 6 basic tests and 13 optional tests. All the basic tests were used in the present study, but only two of the optional tests (2A and 2B) were included. Test 6 (Famous Faces) was adapted to the Dutch situation.

Test 1: Facial Decision:

The stimulus set contained computer drawn pictures of 12 normal faces and 12 nonfaces. The nonfaces missed a facial feature (nose, mouth, eyes), or the features of the face were scrambled. The instruction was to classify the stimuli as face or nonface under time pressure.

Group	Age (S.D.)	7-11 years	12-17 years	19-34 years	Raven SPM (S.D.)
Autist	16;0 (6;10)	5	11	4	39.3 (10.7)
Pre-dip	8;10 (1;2)	32	0	0	33.2 (8.1)
Post-dip	14;10 (1;6)	0	29	0	45.5 (5.6)
Adult	24;9 (3;9)	0	0	30	-

Table 2.1. Mean age and standard deviation (S.D.), the number of subjects in 3 age ranges (7-11 years, 12-17 years, 19-34 years), and the raw scores on the Raven SPM for the 4 groups.

Test 2: Visual Analyses of Facial Features:

A target facial feature (eyes, nose, mouth) was surrounded by 4 features of the same kind. The subject had to match the target feature to one of the four candidates. There were 9 items (3 per feature).

-Test 2A: Complete Context: The same as test 2, but the features were now included in the context of a complete face. The candidate features were placed in the same facial context as the target (see Figure 2.1).

-Test 2B: Partial Context: The same as test 2, but the features were included in a partial context of a face (hair, ears and chin).

Test 3: Visual Analysis of Faces

-Across expression: The subject had to match a coloured photograph of a person with the photograph of this same person but with a different expression in 12 items. There were 9 candidates, all of the same sex.

-Across pose: The same as the previous task, but the target picture differed in pose (full-face or 3/4-profile) from the 9 candidates. The expression of the faces was neutral. The task consisted of 10 items.

Test 4: Visually-directed Semantic Codes

-Sex: There were 10 photographs of men and 10 photographs of women (all unfamiliar). Under time pressure, the subject had to classify the photographs by sex.

-Age: There were 30 pictures of unfamiliar persons: 10 children, 10 adults, and 10 older people. The subject had to categorise, as quickly as possible, by age.

Test 5: Expression Analysis

Three written labels were displayed on the table: "triest" (sad), "vrolijk" (happy), and "zegt 'O'" (says 'O'). Every label corresponded to 4 colour photographs of unfamiliar persons (12 photographs in total). The task was to classify, under time pressure, the photographs into the 3 categories.

Test 6: Famous Faces

The material consisted of 48 photographs of faces, half famous people (frequently on Dutch television) and half unfamiliar people. The subject first classified the photographs into familiar/unfamiliar categories, then was asked to name the people they had designated as famous.

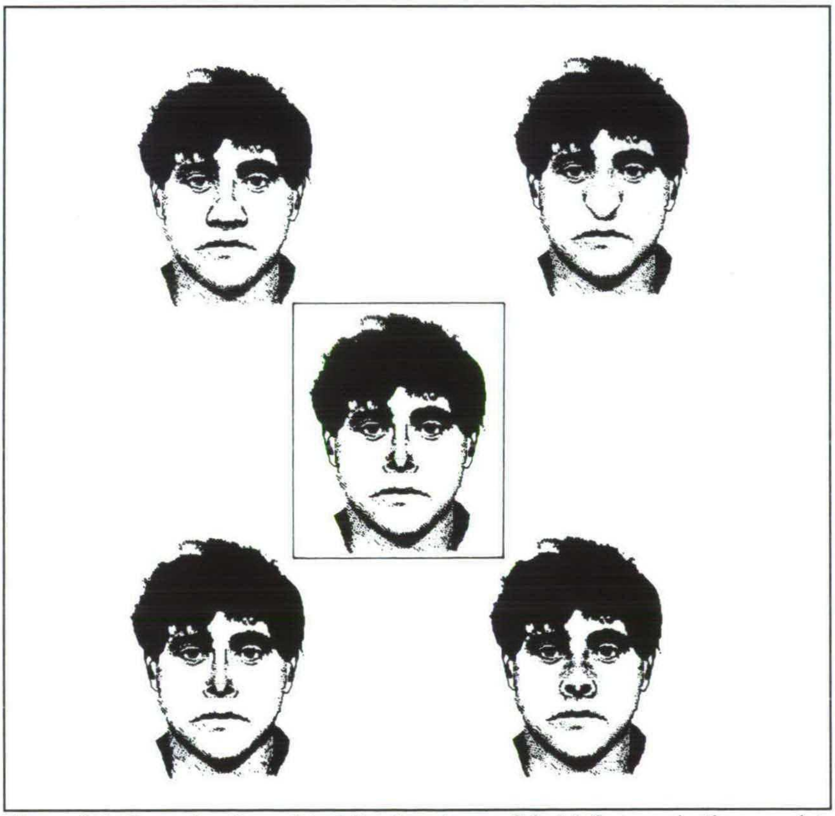

Figure 2.1. Example of test 2A: Visual analyses of facial features in the complete context.

			Adult (n=30)	**Post-dip (n=29)**	**Pre-dip (n=32)**	**Autist (n=20)**
Test	Max.	Rnd.	Mean (lowest)	Mean(lowest)	Mean(lowest)	Mean (lowest)
1. FACIAL DECISION	24	12	23.60 (21)	23.34 (21)	22.84 (20)	23.40 (22)
2. FACIAL FEATURES	9	2.25	8.97 (8)	9 (9)	8.75 (7)	8.95 (8)
2A. complete context	9	2.25	8.63 (6)	8.34 (6)	6.56 (2)	7.00 (2)
2B. simplified context	9	2.25	8.57 (6)	8.59 (7)	7.97 (4)	8.20 (6)
3. EXPRESSION-INDEPENDENT DESCR.	12	1.33	11.93 (10)	11.97 (11)	11.16 (8)	11.40 (10)
POSE-INDEPENDENT DESCR.	10	1.11	9.97 (9)	9.97 (9)	9.28 (7)	9.55 (8)
4. VISUALLY DERIVED CODES: gender	20	10	19.57 (19)	19.79 (19)	19.13 (18)	19.25 (18)
age	30	10	28.60 (23)	29.55 (28)	29.19 (22)	27.95 (21)
5. FACIAL EXPRESSIONS	12	4	11.67 (10)	11.90 (10)	11.56 (9)	11.60 (10)
6. FAMOUS FACES: famil. decision	48	24	45.80 (41)	42.52 (33)	30.81 (19)	34.40 (24)
naming	24	0	21.50 (15)	16.62 (7)	4.47 (0)	8.65 (0)

Table 2.2. Maximal score, random performance, and observed performance (mean value, the lowest value between parentheses) for each test of the clinical test battery.

2.2.2. Results and discussion

The mean scores of the 4 groups are given in Table 2.2. As the performances are near ceiling, a statistical analysis on the mean scores is not appropriate. Therefore, the comparison of the means of the groups is on a descriptive level. Individual scores of the autistic subjects are set against the lowest score of the normal groups.

Normal Subjects

The performances of the adult subjects are near perfect on every test and are very similar to the highly-educated, 20-40 age group of Bruyer and Schweich (1991). The only differences that were found are caused by one subject, a 24-year old male student, who had low scores on tests 2A, 2B and 4B.

The post-dip group (12-17 years old) was not much different from the adult group. These subjects were only somewhat worse on the naming task of famous faces (test 6B), but this is probably due to their knowledge of famous people and not to a different way of processing, as the correlation with age within this group illustrates ($r = .56$, $p < .01$).

Although the pre-dip group (7-10 years old) made somewhat more errors than the post-dip group on almost all the tests, their performances were still extremely good. Only on test 2A (facial features in a complete context) and test 6 (famous faces) were the results significantly worse. Again, this is probably due to the fact that most of the famous faces in test 6 were not yet familiar to these children. The correlation with age was .74 ($p < 0.01$).

There was also a significant correlation between test 2A and age in the pre-dip group ($r = .37$, $p < .05$). The younger the child, the more difficult this task is for him/her. Their good performances on the same task but with isolated features (test 2) show that they are able to detect differences between facial features. It is the context in which the features are placed that confuses the child, suggesting that young children have problems finding the relevant features. After the developmental dip, there is no longer a correlation with age, which suggests that by that time this ability has matured.

The same is true for task 3: the visual analyses of faces, both across expression and pose, is correlated with age before the dip but not after it. This confirms Carey's finding (1992) that young children have problems recognising faces when the faces have undergone some sort of transformation.

Autistic Subjects

The results of the autistic subjects appear to be very similar to those of the normal subjects: they recognise more famous faces when they get older (although they recognise fewer faces than people of their own age), their visual analysis improves, and they also show ceiling effects on most tasks. There are, however, some interesting differences.

Like young children, autistic subjects made more errors on test 2A, where they had to compare facial features in the context of a complete face. But, in contrast to these children, there was no significant correlation with age. Although Figure 2.2 shows that most subjects older than 14 performed better than the younger ones, there are still some subjects who failed on this test. This suggests that at least some autistics do not learn to analyze a face into its relevant details.

The autistics were no worse than the control groups in the recognition of facial expressions. One reason for this may be the type of task. In a face-matching task, the performance is dependent on the ability to compare faces on their physical appearance. In this particular task, there are only three different facial expressions (happy, sad and "says O"), and the physical appearances of these expressions are so different that categorisation can be done without any judgement concerning the emotional content. This task shows that autistics are able to distinguish faces, but this may not be based on the recognition of facial expressions.

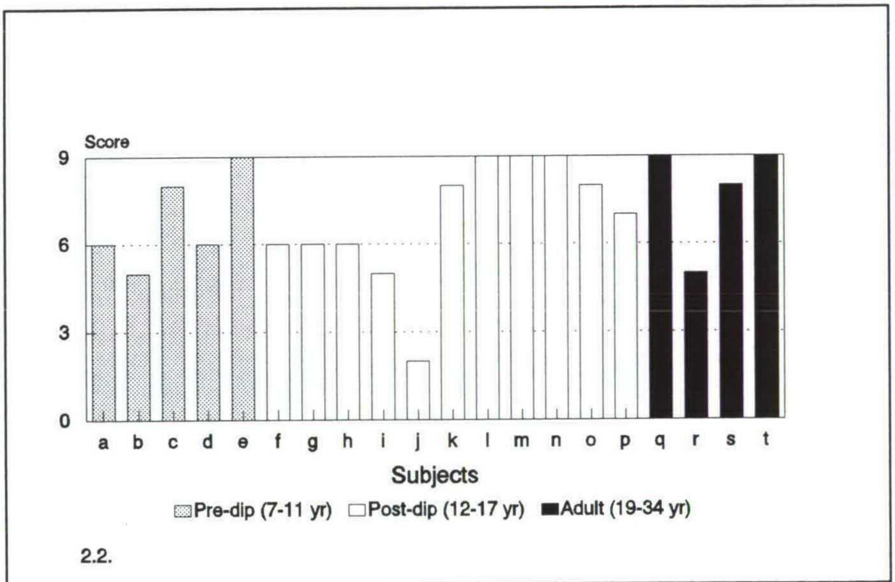

Figure 2.2. Individual scores of the autistic subjects (a t/m t) on test 2A: Complete Context.

2.3. CONCLUSION

This study investigated the face processing system of autistics and children using the task battery for face recognition developed by Bruyer and

Schweich (1991). The main result is that the performance on a task concerning the matching of facial features in the context of a complete face is worse for young children and autistics. The crucial factor in this task is the facial context, which makes it necessary to scan for the relevant feature before the comparison is possible. Other results were near-ceiling or dependent on age (test 6: Famous Faces). Apparently, the battery is easy for both young children and autistics. This suggests that most of the possible face modules are functioning normally at an early age. Only the recognition of faces which have been changed in pose or expression (transformation) and the scanning of a face for a relevant feature are difficult tasks for children. These processes need more time to develop, maybe because they are not modular like the processes involved in the other tasks. The recognition over transformations and the scanning for relevant features are both tasks that could be more dependent on higher-order processes which need more time to develop.

The near-ceiling performances raise the question whether the task battery, which is designed to investigate prosopagnosia, is useful for other clinical populations and young children. The tasks battery is too easy for these groups, which makes it insensitive to possibly subtle differences in face processing between children and autistics.

3. Categorical perception of facial expressions: Categories and their internal structure[1]

3.1. INTRODUCTION

Like a wide range of other perceptual objects, some major facial expressions of emotion are easily recognised and distinguished from one another by normal subjects, even across different cultures (see Ekman, 1994, for a recent overview). Among the many questions raised by this perceptual fluency, a major one concerns its functional basis. Expression perception could be based on an acquired mental lexicon of facial expressions built up in the course of communicative development and under the control of general learning principles. It might also reflect a biologically endowed ability for expression recognition. In the latter case, perception of facial expressions would proceed by assigning tokens of facial expressions to cognitive categories representing the basic elements or the primitives of the human facial emotion lexicon.

This latter approach to categorisation ability is well illustrated by research on speech perception. Liberman (in press) presents a comprehensive discussion of the early rationale for categories in speech perception. The basic methodology of speech experiments investigating categorical perception (CP) took advantage of speech synthesis that became available in the sixties. A typical experiment presented listeners with a synthetically created multi-step continuum inserted between two end points made up of two natural tokens. The goal of speech researchers was to study the subjective perception of a linguistically meaningful boundary emerging from the acoustic continuum.

The original CP experiments (Liberman et al., 1957, 1967; Liberman, in press, for a historical overview) challenged a common intuition that categorisation of speech sounds would vary monotonically with the physical stimulus value. Instead, a clear discontinuity in subjective judgements of phonetic information was observed. While discussions on the theoretical interpretation of CP have continued, it is generally agreed that the basic phenomenon of CP has the following profile: (a) stimulus identification has a

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[1]Accepted for publication as: de Gelder, B., Teunisse, J.P. & Benson, P. (in press). Categorical perception of facial expressions: Categories and their internal structure. *Cognition and Emotion.*

Research presented in this paper was partly supported by a grant to the first author (Ministry of Education and Scientific Research of the Belgian French Community, Action de Recherche Concertee 'Language processes in different modalities').

The studies were presented at the 30th Meeting of the Psychonomic Society, St. Louis, November 1994, at Haskins Laboratories and at the Psychology Department, State University of Arizona, Tempe in January 1995. We thank P. Piree and E. Mulder for assistance in testing the subjects. We are indebted to Nico Frijda, Paul Bertelson and Jean Vroomen for valuable discussion.

steep slope with a somewhat abrupt change in labelling probabilities somewhere along the continuum corresponding to the hypothetical category boundary; (b) a peak in sensitivity is found in the discrimination function at the category boundary at a location corresponding to the change in labelling probability; (c) within-category discrimination is at chance level; (d) discrimination is predicted by the labelling functions. In the classical analysis of the CP paradigms, these requirements should be met jointly (see Repp, 1984, for a more detailed analysis and critical approval of each). While each of these requirements has been criticised, there is a clear baseline requirement resulting from those criticisms. The pattern of evidence that is desirable for CP is that there is a maximum in the discrimination performance and that this is found at that point in the continuum where in the identification task the two responses are equiprobable (the 50% identification point). Accessorily, another categorical characteristic might be a slowing down of the identification decision at about the same point.

It is important to clarify the analogy between CP in speech or in facial expressions for theoretical as well as for methodological reasons. The basic notion underlying the analogy is that expression categories emerge in the perception of a continuous stimulus domain. In contrast to CP experiments where one dimension like VOT is manipulated to synthesise a continuum, in the stimuli used here multiple properties of the face are covaried. While very little is known about the facial carrier of expressive information, it seems reasonable to expect the face as a configuration to play an important role here. There is evidence that some semantic aspects of face perception critically rest on the presence of the configuration as illustrated by the inversion effect (Yin, 1969; Valentine, 1988) and the composition effect (Young, Hellawell & Hay, 1987). A method of facial synthesis where a large set of facial parameters are covaried simultaneously converges with this notion that the configuration is important for conveying expressive information. But covariation of different stimulus aspects may create problems of its own as we will discuss below.

The present study dealt with four emotions that are generally taken to be basic (anger, fear, happiness and sadness), arranged in three continua (angry/sad, happy/sad and happy/afraid). As a matter of fact, it has been argued that these four emotions are those which can best be defined along three separate dimensions of positive/negative, approach/avoidance, and level of arousal (Frijda, 1986). These emotions also appear to be independent of the commonly used verbal labels (Ekman, Friesen & Ellsworth, 1972) and might be interpreted as expressing the Darwinian view of the basis of emotion in action patterns (Frijda, 1986). Concentrating on these emotions, we chose to leave out other candidates like neutral since it is not clear how a neutral expression relates to perception of emotions in faces (in production terms, this is the resting state). The issue of what constitutes a basic emotion as contrasted with complex or composite emotions is a vexed one (see Frijda, 1986, for an overview of various ways of defining basic emotions). It is to be expected that present taxonomies of even so-called basic emotions may still represent a heterogeneous set. For example, anger and fear, the two most explored emotions, are very different with respect to what perception of these facial expressions means for the perceiver. The study of CP for emotions is in its infancy and these are among the crucial issues that future research will have to address.

Etcoff and Magee (1992) observed categorical perception of facial expressions using line-drawings. In accordance with the standard formulation of categorical perception, subjects showed dichotomous identification behaviour and were better able to discriminate between stimuli on different sides of the category boundary than within the same category for the same physical distance between the members of a pair. The present study pursues the issue of categorical perception by using real photographs and a sophisticated digital image morphing technique to create intermediate stimuli between two prototypical facial expressions (Benson & Perrett, 1991; Benson, 1994). Experiment 2 presents the same expression continua as used in Experiment 1, this time using upside down presentation. In Experiment 3 we have investigated the existence of CP in children while also adding a a goodness rating task for the stimuli from adults as well as children.

3.2. EXPERIMENT 1: THE CP TASK WITH ADULTS

In this experiment, the discrimination and identification of facial emotions from photographs of faces by adult subjects were examined for evidence of categorical perception. Three continua, each obtained through a morphing procedure between two posed prototypes, were used. As explained in the Introduction, the most generally agreed manifestation of categorical perception is the occurrence of a peak in discrimination performance around the point on the continuum at which identification reaches 50%. One problem in devising a test of that notion is the existence of individual differences in the location of that point. The solution we adopted consisted of reducing the discrimination data of each subject to two values, one corresponding to the predicted peak and the other to regions of the continuum on either side of the peak. The same form of analysis was applied to reaction times which were measured in both the discrimination and the identification task.

3.2.1. Method

Subjects

Twenty-four undergraduate students from Tilburg University, 12 of both sexes, aged 18-26, were paid for participation in one experimental session.

Materials

Three sets of 11 computer-generated continuous tone black and white photographs of faces were used (Appendix 1). Each set constituted a continuum of facial expressions between two naturally posed exemplars taken from standardized material (Ekman & Friesen, 1976). The continua extended from angry to sad, from happy to afraid and from happy to sad respectively. The original photographs were digitized and intermediate faces were created using a morphing program (Benson & Perrett, 1991; Benson, 1994).

The morph transformation started with delineation of the digitised images of the two original images. Landmarks were placed manually on corresponding critical points of the two faces, using a graphical tool. The transformation from one extreme expression to the other was effected in nine intermediate steps. The transformation affected both the feature configuration (warping) and the tonal information (skin texture or pigmentation). The weighted blending procedure was based on linear interpolation between point-to-point pixel intensity values.

Procedure

Subjects were tested individually in a sound attenuated cabin in the laboratory. A monitor (Commodore 369SX at 256 grey levels) was placed at a distance of 1.5 m from the subject, and the 9.5 x 6.5 cm photographs subtended a 3.6 x 2.5 degrees visual angle.

Each subject worked successively on the three sets of photographs, in counterbalanced order. For each set, two tasks were administered: first the ABX discrimination task, then the identification task.

In the ABX task, each trial started with an auditory warning signal, followed after 800 msec by successive presentation of three photographs for 1 second each, separated by one-second intervals. The first 2 pictures, A and B, were always different, and the third, X, was identical either to A or to B. The subject was instructed to indicate which picture, A or B, X was identical to by pressing one of two buttons, labelled A and B, with a finger of either the left or the right hand. Reaction time was measured from appearance of the X stimulus to the response. The warning signal of the next trial appeared two seconds after the subject's response. A and B were always two steps apart on the continuum, so nine comparisons were possible. For every comparison, the four possible orders of presentation (ABA, ABB, BAA, BAB) were presented three times each. The resulting 108 trials were presented in random order. The task started with 10 practice trials with faces showing several expressions.

In the identification task, the 11 photographs of the set were presented one by one, and the subject identified each stimulus by pressing one of two buttons, with labels bearing the Dutch names of the two end emotions of the continuum. A trial was announced by the same auditory warning signal and was followed after 800 msec by the face which stayed on for one second. Reaction time was measured from appearance of the stimulus to start of the response. The warning signal for the next trial appeared two seconds after the subject's response. Each of the 11 stimuli was presented three times in random order, giving a total of 33 trials.

3.2.2. Results

The total identification function (% responses) for each continuum appears in Figure 3.1a. All three curves have the usual sigmoidal shape. For each continuum, the identification responses of each subject were submitted to a logit transformation (Finney, 1964), which provided estimations of the 50% point and of the slope of the identification function at that point. The means of these two variables are given for each continuum in Table 3.1.

The ABX discrimination data were compared subject by subject to the prediction from the identification data, following the principle described in the introduction. Given that the AB points used in the ABX task were 2 steps apart, each subject's 50% identification point falls into two successive AB intervals, and the peak discrimination is supposed to fall in one of these. For instance, for a subject whose 50% point is at 4.2, the peak must occur in one of the two intervals 3-5 and 4-6. We chose to consider the two intervals as containing the predicted peak. Our test consisted of calculating two measures of discrimination performance for each subject: a 'peak performance' value which is the mean of the observed % correct responses over the two peak intervals, and a 'non-peak performance' value, which is the mean of the same % correct over the 7 remaining intervals. Significance was assessed using the t-test.

The results for each continuum appear in Table 3.1. The prediction of higher performance in the peak intervals is supported for each continuum. It can be noted, on the other hand, that discrimination is definitely above chance in the non-peak intervals, contrary to what early formulations of categorical perception predicted (Repp, 1984; but see Harnad, 1987). Given our decision to test the discrimination data on a subject by subject basis, traditional figures showing mean performance across subjects for each whole continuum, such as those presented by Etcoff and Magee (1992), will not be provided because they do not show the critical contrast on which the present analysis is based.

RTs in both the identification (Figure 3.1b) and the ABX task were submitted to subject-by-subject analysis following the same principle as the correct discrimination data. For identification, the prediction for categorical perception was slower RT for the two photographs on either side of the 50%

point (the "peak RTs") than for the other items. The results which appear in Table 3.2 support the prediction for all three continua.

For the ABX task, the prediction was shorter mean RTs for the two "peak intervals" than for "non-peak" ones. It was supported for none of the three continua.

	Angry-Sad	Happy-Sad	Angry-Afraid
Identification			
50% point	4.65	4.42	4.94
Slope	61.28	62.24	57.12
Discrimination			
Peak	68.9	73.5	81.7
Non-Peak	64.0	68.0	76.0
t	2.28	2.28	3.27
df	23	23	23
2-tailed p	.032	.032	.003

Table 3.1. Experiment 1 (upright faces). Identification and discrimination results.

	Angry-Sad	Happy-Sad	Angry-Afraid
50%	942	982	1043
Rest	809	748	837
t	5.12	7.31	6.57
df	23	23	23
2-tailed p	.000	.000	.000

Table 3.2. Experiment 1 (upright faces). Mean identification reaction times for 2 photographs around the 50% identification point and all other points together.

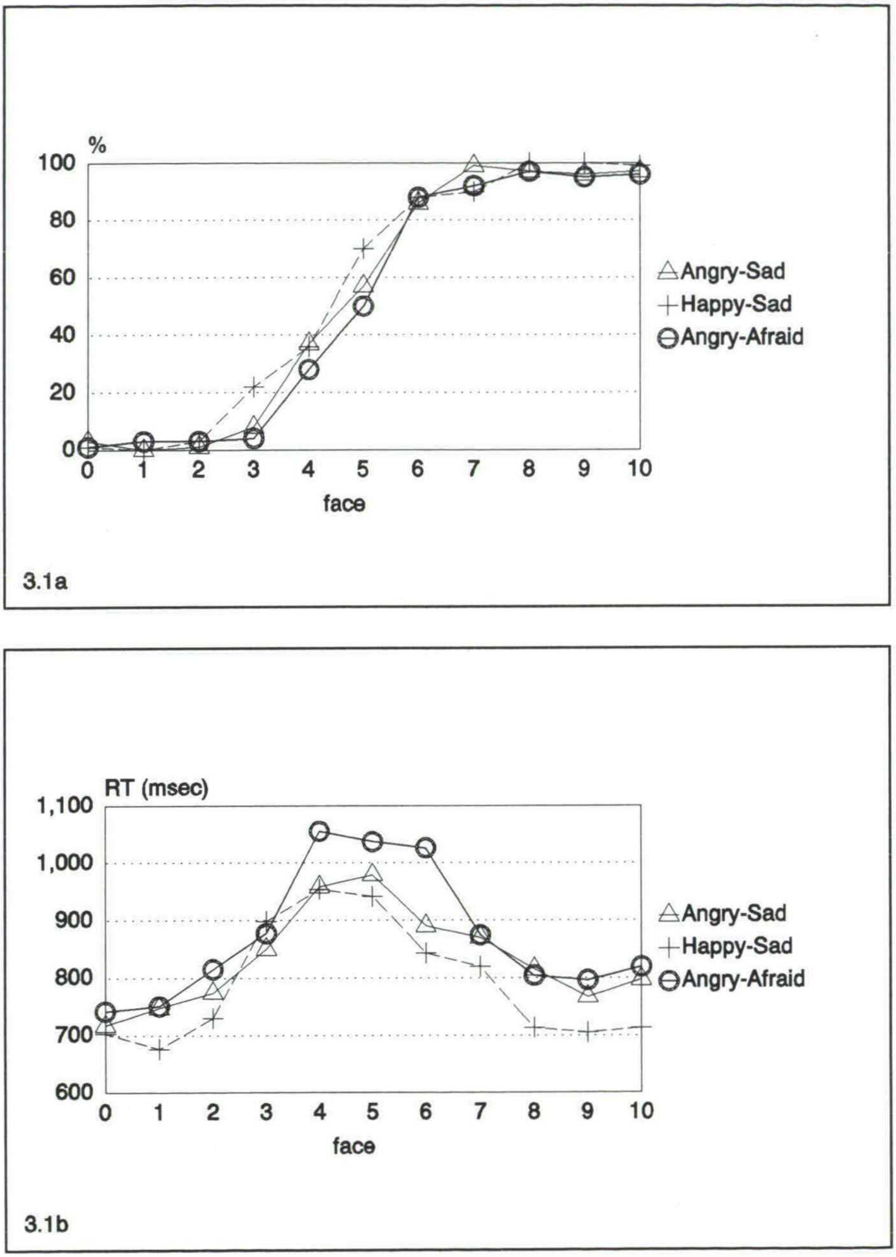


Figure 3.1. Experiment 1 (upright faces).
a. Mean response percentages for the three continua in the identification task.
b. Mean reaction times for the three continua in the identification task.

3.2.3. Discussion

Two aspects of the results seem to indicate some degree of categorical processing of the material we have been using. The first aspect is higher discrimination performance in the ABX task for pairs of items falling across the 50% identification point. The second is slower identification RTs for items bordering the 50% point than for items further away. Each of these effects was tested on predictions for individual subjects and was found significant for each of our three continua.

Before drawing any strong conclusion from these results, one must, however, consider the possible role of alternative, non-categorical, factors in bringing them about.

One possibility that has been mentioned is unequal spacing of items along the continuum from the psychophysical point of view. The morphing procedure produces equal physical steps between adjacent items on each continuum, at least for these points on the faces to which it was applied. But equal physical distances can give rise to unequal perceptual distances, and it was suggested that one should measure the latter using one of the many psychophysical scaling methods available. The problem, however, is that category boundaries are one of the factors that can create distortions between physical and perceived distance. How to separate the contribution of hypothetical non-categorical factors from that of categorical ones (to avoid throwing the baby out with the bathwater) is not immediately apparent. On the other hand, for non-categorical variations in psychophysical step sizes to produce the present results, larger steps would have to coincide with the 50% identification point of a majority of subjects on each of our three continua, which is rather unlikely.

A potentially more serious possibility is that more accurate discrimination towards the middle of the continuum, combined with slower identification, would happen on any continuum which, like the present ones or those explored by Etcoff and Magee, extends between exemplars of just two categories. In such a situation, only two responses are proposed in the identification task and are probably available to the subject for short-term retention in the discrimination task. The problem does not arise for other domains in which CP has been studied with continua extending to several categories, like the /ba/-/da/-/ga/ continuum for speech (Miller, 1994) or the hue wheel for colour.

It appeared to us that a useful control of the possible influence of the dichotomization artefact in our situation would consist of running the same two tasks with the same material presented upside-down. Upside-down inversion has frequently been used in research on face perception as a control for the role of non face-specific properties of the material (see Valentine, 1988, for a review). In the present context it may not only shed light on the dichotomization issue, but may also address another concern, that of step sizes.

3.3. EXPERIMENT 2: THE INVERTED CP TASK

For the reasons explained in the discussion of Experiment 1, a new group of adult subjects performed the same tasks, ABX discrimination and identification, with the same material presented upside-down.

3.3.1. Method

Twelve undergraduate subjects from Tilburg University, six males and six females, participated in one session. They were paid for their participation and none had been previously exposed to our material. In the Happy-Sad continuum, one subject had a 50% identification point that fell out of the 1-9 range and was excluded from further analyses.

The material and procedure were as in Experiment 1, the only difference being that the pictures were presented upside-down throughout.

3.3.2. Results

The total identification function for each continuum is given in Figure 3.2a. It appears that the curves have more or less the customary sigmoidal shape for the happy-sad and angry-afraid continua, although with a shallower slope than in Experiment 1. But for the continuum angry-sad, the curve is approximately bell-shaped. Examination of individual data shows that about half the subjects have a negative slope, indicating a tendency to call inverted angry faces sad and vice versa. These observations precluded, of course, further analyses of the data concerning this particular set of pictures, which would require valid estimations of the category boundary.

For the remaining sets, happy-sad and angry-afraid, the ABX data were submitted to the same analysis as in Experiment 1. The results appear in Table 3.3. For neither of the two continua is there a significant difference between discrimination performance on peak and nonpeak comparisons respectively. On the other hand, overall discrimination performance is above chance level for the two continua.

Identification RTs for the same two continua were, as in Experiment 1, analyzed according to proximity to the estimated category boundary. The results which appear in Table 3.4 are similar to the corresponding ones in Experiment 1: RT is slowed down for the pictures bordering the 50% point in comparison with the rest of the points (Figure 3.2b). With 2-tailed t-tests, the effect is significant for continuum happy-sad and falls just short of the .05 level for angry-afraid. But one could argue that since the difference was predicted, a 1-tailed test could be applied. In that case, the difference would be significant at $p < .028$.

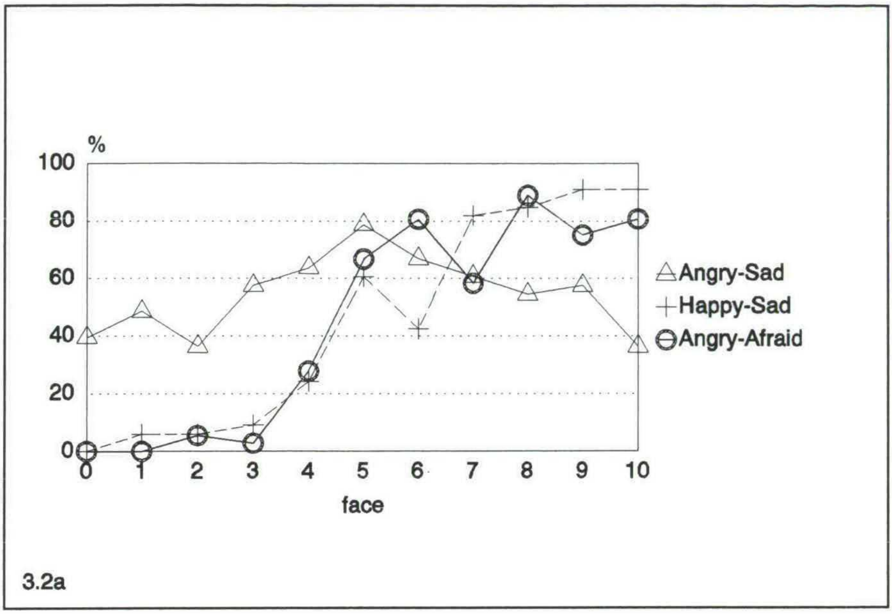
For the ABX task, there was again no speed difference between comparisons across and those on one side of the boundary.

	Angry-Sad	Happy-Sad	Angry-Afraid
Identification			
50% point	-	5.58	5.72
Slope	-	43.64	40.07
Discrimination			
Peak	-	62.6	76.3
Non-Peak	-	61.5	70.3
t	-	.30	1.41
df	-	10	11
2-tailed p	-	.773	.185

Table 3.3. Experiment 2 (inverted faces). Identification and discrimination results.

	Angry-Sad	Happy-Sad	Angry-Afraid
50%	-	910	930
Rest	-	806	802
t	-	2.77	2.13
df	-	10	11
2-tailed p	-	.020	.056

Table 3.4. Experiment 2 (inverted faces). Mean identification reaction times for 2 photographs around the 50% identification point and all the other points together.



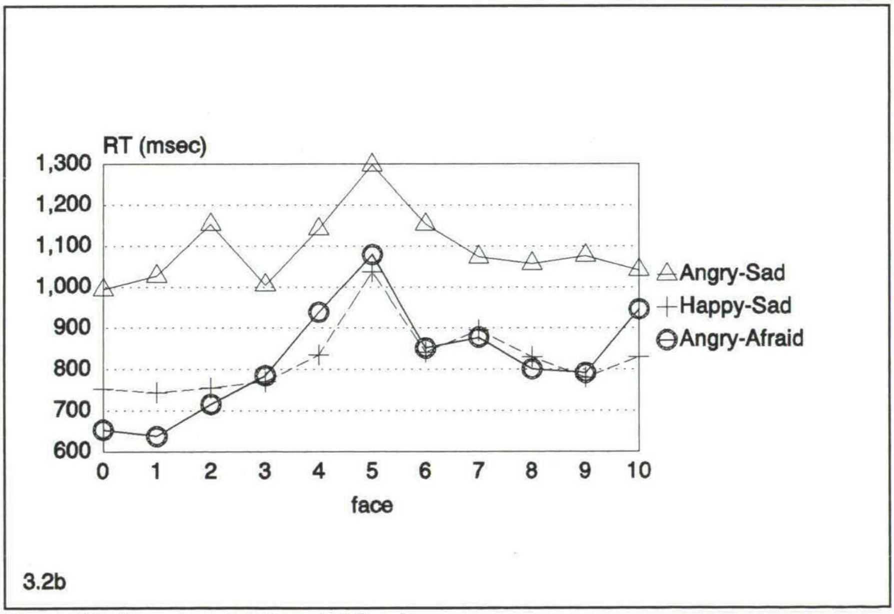


Figure 3.2. Experiment 2 (inverted faces).
a. Mean response percentages for the three continua in the identification task.
b. Mean reaction times for the three continua in the identification task.

3.3.3. Discussion

For the pictures in the angry-sad set, the present subjects produced erratic identification performance, which made analysis of other data concerning these stimuli impossible. Apparently, any decision as to whether these pictures are perceived as belonging to the end points of either of the two emotions is made unaccessible by upside-down inversion.

For the other two sets, for which the analysis of Experiment 1 could be carried out, contrasting results were obtained for ABX discrimination performance and identification RTs respectively.

The discrimination performance peak on comparisons straddling the category boundary is no longer observed. Thus, the notion of a dichotomy artefact, suggesting that such a peak should occur toward the middle of any continuum extending between two different exemplars, is not supported and the positive result obtained in Experiment 1 cannot be explained by that particular mechanism. The present finding, it may be noted, would also create difficulties for an interpretation based on psychophysically unequal steps: how inversion of the pictures would reinstate equality is not evident.

In the identification task, on the other hand, the slower RTs around the category boundary are observed again. This particular effect is thus not specific for emotion processing and may result from a dichotomy artefact or some other general-type mechanism.

Expression information and the inversion paradigm has not, to our knowledge, been used to explore the issue of the configural basis of facial expressions. As inversion drastically reduces the CP effect, we may infer that the information relevant for CP might be carried by the facial configuration. Configurational information is more critical for making face judgements than for judging other perceptual objects (Diamond & Carey, 1986). The issue of relative versus absolute inaccessibility of expressive information following inversion clearly requires further exploration.

Experiment 3 was set up to generalise the findings to young children. A new task was also added. Studies by Miller and collaborators have shown systematic variations in goodness judgements within the same category and have argued for a graded internal structure of phonetic categories (see Miller 1994, for overview and discussion). Miller and collaborators have also found that this prototype structure is reflected in reaction times in the sense that the higher the goodness ratings, the less time it takes listeners to identify a stimulus. To what extent might this situation carry over to the domain of facial expressions? In our case, this would mean that two different expressions, both identified as 'anger', can still clearly be discriminated. The reason for this good within-category discrimination would be that one stimulus is perceived as a better expression of anger than another. Note that goodness of category membership may matter comparatively little for speech stimuli where categorical decisions are only one step in a whole process of word recognition. In contrast, a judgement about goodness of emotion expression is likely to affect perception and action much more directly.

3.4. EXPERIMENT 3: THE CP TASK WITH ADULTS AND CHILDREN

The main objective of the present experiment was to see whether the evidence for categorical perception obtained in Experiment 1 with adults could be replicated with children. Since one might expect children to have lower discrimination capacity than adults, the inter-item space for the ABX task was set at three steps. Consequently, new adult subjects had to be tested for comparison purposes. Another change from Experiment 1 was that the subjects were asked to rate the photographs' goodness as exemplars of their category.

3.4.1. Method

Subjects

Twenty-four 9- to 10-year old children, 12 of both sexes, from a public school in Tilburg, were tested individually in a quiet room at their school. Fifty-nine undergraduate students, aged 17-21, participated in a short session each, 24 with the angry-sad continuum, 18 with happy-sad and 17 with angry-afraid. None of them had seen the material before.

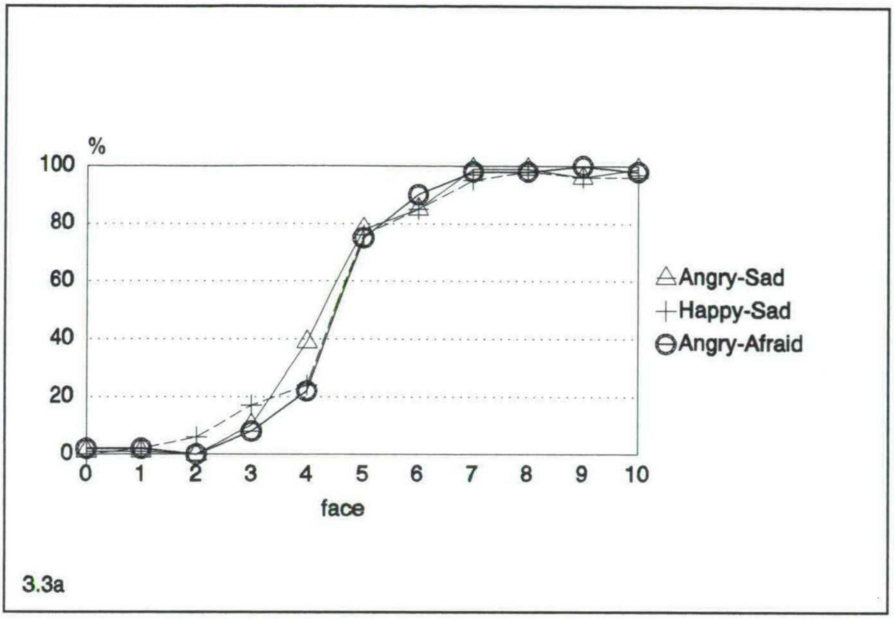
Procedure

For each continuum, three tasks were administered successively: the ABX discrimination task, the identification task and a goodness rating task.

The ABX task was run with three-step intervals instead of two. Apart from that, the administration procedure for both the ABX task and the identification task was the same as in Experiment 1.

For the goodness rating task, each set of photographs was divided into two subsets, one containing the first six items and the other one the last six items. The pictures were presented on the screen in the same conditions as in the identification task. The subjects expressed their ratings on an answer sheet which mentioned the expression to be rated and offered a 10-point scale. The instructions specified that a rating of 1 meant no expression of the relevant emotion and 10 an excellent expression.

3.4.2. Results



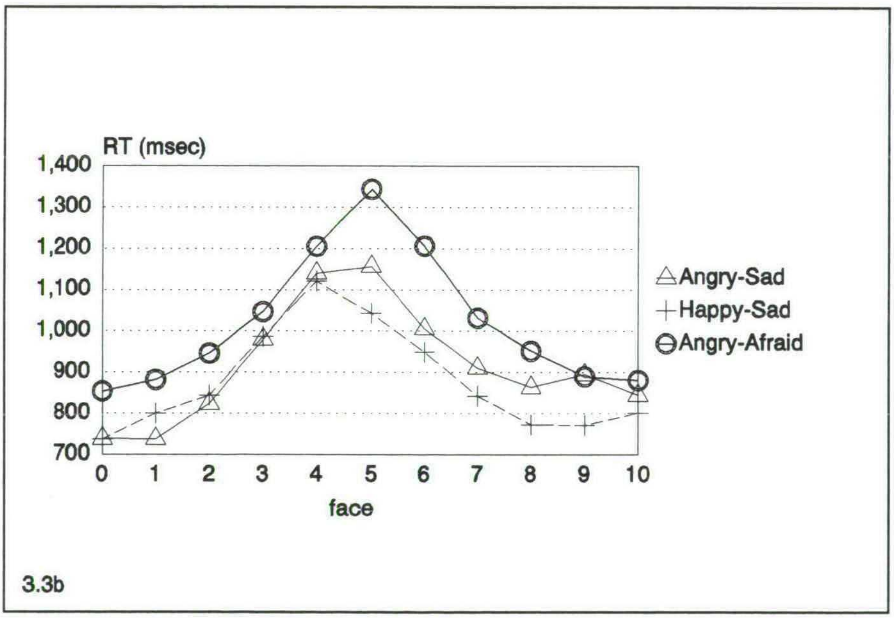
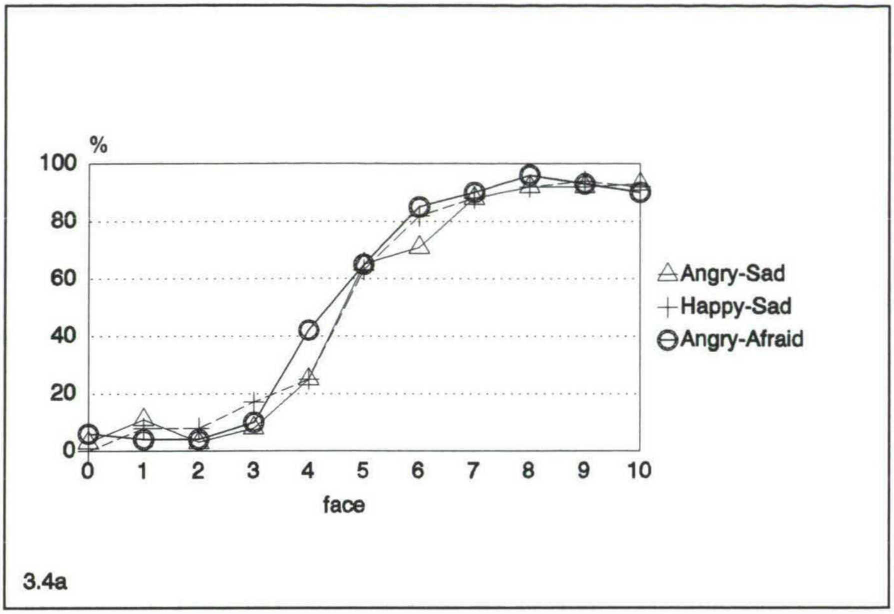


Figure 3.3. Experiment 3 (upright faces): adults.
a. Mean response percentages for the three continua in the identification task.
b. Mean reaction times for the three continua in the identification task.



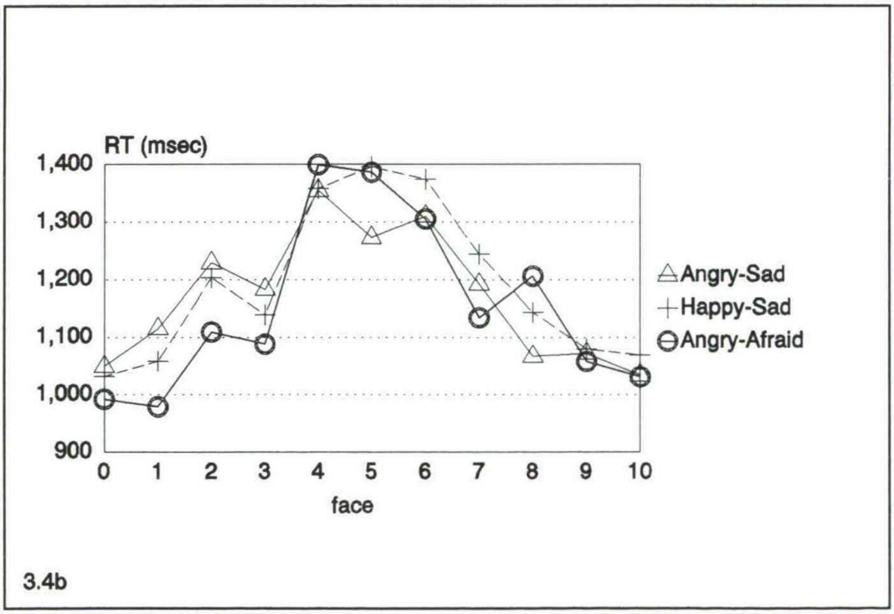


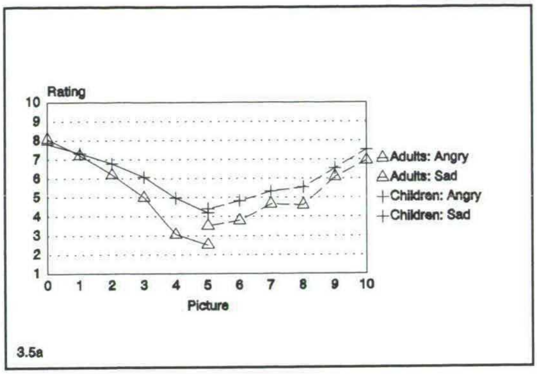
Figure 3.4. Experiment 3 (upright faces): children.
a. Mean response percentages for the three continua in the identification task.
b. Mean reaction times for the three continua in the identification task.

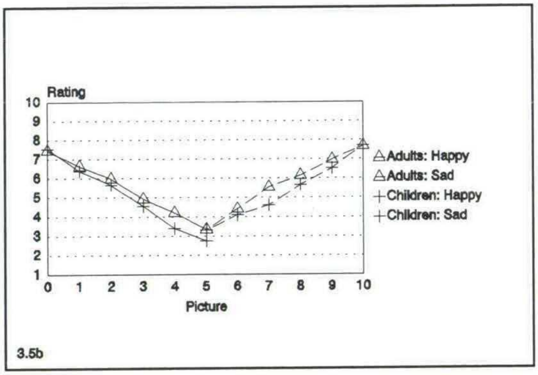
	Angry-Sad	Happy-Sad	Angry-Afraid
A. Adults			
Identification			
50% point	4.42	4.47	4.56
Slope	63.56	63.48	68.23
Discrimination			
Peak	81.1	88.00	90.6
Non-Peak	74.6	85.09	90.9
t	3.16	1.70	-.28
df	23	17	16
2-tailed p	.004	.108	.783
B. Children			
Identification			
50% point	4.92	4.77	4.67
Slope	51.28	55.54	54.17
Discrimination			
Peak	63.1	69.7	82.6
Non-Peak	60.8	64.3	78.4
t	.98	2.42	2.89
df	23	22	22
2-tailed p	.335	.024	.008

Table 3.5. Experiment 3 (upright faces). Identification and discrimination results.

	Angry-Sad	Happy-Sad	Angry-Afraid
A. Adults			
50%	1164	1122	1282
Rest	866	825	964
t	5.91	5.88	4.99
df	23	17	16
2-tailed p	.000	.000	.000
B. Children			
50%	1295	1404	1352
Rest	1143	1143	1109
t	3.55	6.27	5.31
df	23	23	23
2-tailed p	.002	.000	.000

Table 3.6. Experiment 3 (upright faces). Mean identification reaction times for 2 photographs around the 50% identification point and all the other points together.





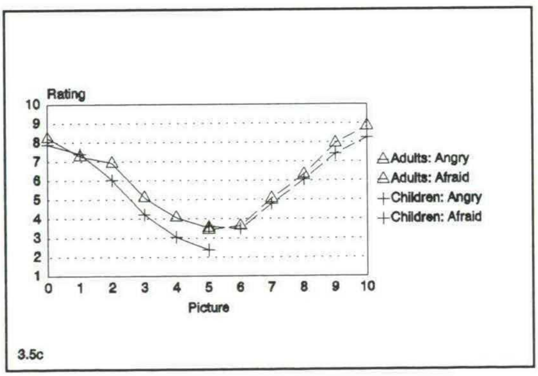


Figure 3.5. Experiment 3 (upright faces).
a. Ratings for angry-sad.
b. Ratings for happy-sad.
c. Ratings for angry-afraid.

The total identification functions of children and of adults are given for each continuum in Figures 3.3 and 3.4. The children's functions have somewhat shallower slopes than those of the adults, which is confirmed by the values appearing in Table 3.5. Adults' functions are comparable to those obtained in Experiment 1.

In the ABX task, since we now used 3-step intervals, each subject's 50% identification point falls in three successive intervals. Therefore, the predicted peak discrimination is measured by the mean accuracy over these three intervals, and the non-peak by the mean over the remaining five intervals. The data from one child could not be used in the analysis of ABX performance on the happy-sad and the angry-afraid continua, because his 50% identification points fell for these continua outside the 2-8 range. The results appear in Table 3.5.

Before considering the peak-nonpeak contrast, one can note that the performance of children on nonpeak discrimination is lower than that of adults. The latter is, as expected, superior to that observed in Experiment 1 for two-step discrimination.

In children, peak intervals superiority is significant for the continua happy-sad and angry-afraid. On the angry-sad continuum, the peak-nonpeak difference is in the expected direction but falls short of significance. One may note that this continuum is the one on which non-peak discrimination is lowest, not only in the children but also in adults of both this experiment and of Experiment 1, so that a floor effect must have prevented the manifestation of the peak-nonpeak difference in some of the children.

For the adults, the pattern of statistical significance is the opposite of that of the children. The peak interval superiority is significant for angry-sad, but not for happy-sad or angry-afraid. For the two latter continua, non-peak discrimination is at high level, 85 and 91% respectively, and one may consider the possibility of a ceiling effect. Finally, it should be noted that for the case of happy-sad, application of a 1-tailed test, which the existence of a prediction would justify, would provide a probability level of .054, very close to significance.

In identification RTs (Table 3.6), the significant slowing down obtained in other experiments is again observed for every continuum, for both children and adults. No peak-nonpeak difference is obtained for discrimination RT.

Results of the goodness rating task appear in Figure 3.5. In every category, the mean rating increases monotonically with closeness to the prototype. This pattern is observed in both children and adults. As comparison of Figures 3.3, 3.4 and 3.5 suggests, the rating data correlate strongly with the identification RTs for the same pictures, in both children and adults. Of 12 product-moment correlations (2 groups x 3 continua x 2 prototypes) 10 are significant at $p=.05$. The only non-significant ones are for sadness on the angry-sad continuum in adults ($r=.76$) and for anger on the same continuum for children (r=.79).

3.4.3. Discussion

The experiment was set up to see if the evidence for categorical perception obtained in Experiment 1 would be replicated with children under 10 years old. The main criterion for categorical processing, a peak in discrimination performance around the category boundary, is observed for all three continua, but fails to reach significance for the more difficult one, angry--sad. It might be the case that some floor effect played a role in that case. Adults were tested on the same tasks for comparison. The peak superiority effect was only partially replicated in this easier discrimination task, and typically with the two most difficult continua. The absence of effect with the easier angry-afraid material may be partly due to a ceiling effect. One can, as a matter of fact, wonder whether resorting to adult control subjects was a sound decision, given that absolute performance level is of little relevance to the main theoretical question. The direct comparison of the children in the present experiment with the adults in Experiment 1 at the level of performance profile is probably more instructive. The profile of discrimination performance of the two groups are remarkably parallel and allow the same conclusions.

Experiment 3 thus shows that the age group examined here categorises facial expressions in a way very similar to that of adults. The only difference concerns speed of response, a variable that is known to increase with age. Facial expression perception as examined here does not seem to be affected by the developmental difference in processing style of younger children, such as the "developmental dip" (Carey, 1981).

Finally, adults as well as children provide clear goodness ratings for all the expressions studied. Rated goodness decreases as distance from each natural unmanipulated expression increases. Moreover, there appears to be a systematic relation between RTs in the identification task and stimulus ratings. Further research would need to explore this relationship and its importance for understanding the discrimination results.

3.5. General discussion

This study addressed the question whether facial expressions are perceived categorically and if so, whether such is the case for adults as well as for younger children. Combining the different results from the three tasks and the three experiments, it appears that, generally speaking, the facial expressions studied here are clearly perceived categorically by adults as well as by children. At the same time, subjects appear to judge reliably whether a given facial expression is a good or a poor example of the facial expression represented. We will comment on these results and discuss whether inferences about underlying categories of facial expression perception can be based on these behavioural results.

The possibility that categorisation behaviour results from learning was first argued for by Lane (1965). A learning explanation stresses the conceptual as opposed to the perceptual status of categories and focuses on the role of labels and their role in memory to explain categoricity. As understood in this context, learning explanations tend to reduce the power of inferences about underlying biological functional categories. Artificial neural networks using a back-propagation learning rule have been used to simulate CP effects (Harnad et al., 1994). Indeed, such networks can be configured to exhibit categorical behaviour very much in the manner of human and animal performance. These implementations are not a substitute for human subjects because they cannot presently be directly related to high-level categorical behaviour. Networks operate heuristically and algorithmically and can be sensitivity-tuned to yield CP, but they are not capable of operating at the same cognitive level as a human subject during an expression task. Whilst examination of hidden unit weights at the learning stage may give some indication of the magnitude and consistency of just noticeable differences, one cannot assume these will reflect conscious or unconscious human discrimination grounded in terms of category symbols or categories in the mind.

We have noted the possibility that CP findings in the identification task might be based on task-specific factors. Note that a methodology in which bipolar continua are combined and the anchor point A of a continuum a-b is also that of another continuum a-c etc. (Calder et al., in press) does not provide a full answer to that objection of possible task artefacts. In the present study, Experiment 2 addresses that issue satisfactorily. Our Experiment 2 serves as a control for the effect of such factors. Improving upon the CP methodology would require studying categories in a multidimensional space. It has been illustrated that just noticeable differences play a less significant role when more than two categories are present as in a high-dimensional expression space (each expression represents one dimension; Benson, 1992, 1995, in prep). Facial expressions are highly interactive in nature and the presence of valid blended emotions are known (e.g., Ekman & Friesen, 1976; Nummenmaa, 1988; Katsikitis & Benson, submitted). Only in a high-dimensional space can such phenomena be properly assessed (Benson, 1995, in preparation).

There are two important and potentially confounding factors in similarity assessments and ABX discriminanda for CP research and are especially relevant to discussion of higher-order stimuli and semantics. Firstly, a given facial expression may be signalled by only a few facial features. How these features interact, together with their own relevance, is clearly an important consideration; only a portion of the AB similarity images may be useful - but which? Similarity judgements of pairs along a Happy-Angry continuum are more likely to depend on image-based (congruent) features, whereas ABX discrimination will draw upon different salient features (as in the identification task). Secondly, the strength of the communicated affect signal, or its 'energy' (Benson, 1995, in prep; Katsikitis & Benson, submitted), provides a simple and clear indication that some (category) exemplars may not be as representative or as good members as others. This is particularly evident in Etcoff and Magee (1992) and may help account for the failure to find categoricity of Surprise (Benson, 1995). It should be clear that these two factors (feature salience, energy) are intrinsically related and therefore one should expect to observe modulations in the magnitude, or absence, of CP effects dependent on category verisimilitude (Benson, 1995). Prototypical or enhanced expressions may better qualify for category membership, the prediction being that optimal representations will yield optimal CP.

In the present study, as in previous studies using the CP paradigm, subjects are good at discriminating between 2 stimuli that belong to the same category. This finding is compatible with CP conclusions and it has been argued (Harnad, 1987) that there are no good grounds for expecting discrimination ability within category pairs to be at chance level. Nevertheless, the issue of the basis of good discrimination ability is worth pursuing because of its importance for understanding facial expression perception and whether or not it is category based. Examining the goodness ratings and their possible relation to this discrimination ability may be a first step.

We mentioned earlier that a situation comparable to a first stage of physical information processing may not obtain in the case of facial expression perception. Like sounds, faces are complex stimuli, but unlike the former, faces are likely to be perceived configurationally rather than componentially with perception being built up from separate features. A two-stage model of facial expression perception in which better than expected discrimination would be due to continued post-categorical presence of low level differences is thus not very likely. Better-than-chance discrimination, thus, results from the fact that subjects, while assigning various stimuli to the same category, nevertheless note critical differences in the extent to which these different same-category stimuli represent the expression typical for that category.

Two interesting hypotheses for future research are that goodness judgements are predominantly related to perceived quality of expression of the stimulus as a whole and that subjects do not base their response on separate components of the face only.

We noted in the beginning that very little is known about perceptual expression categories and that claims about a functional architecture and the emotional categories of which it is made up would be well advised to look for converging evidence at least in development in neuropsychology. The present study presents such developmental data. These allow us to make the comparison with results obtained with a group of autistic subjects. Deficits in the perception of facial expressions have been documented with this population in several recent studies. The prediction is, thus, that an impairment would also be observed with the CP task. This was indeed the case (Teunisse & de Gelder, submitted-a). As a group, the autistic subjects showed poorer identification and discrimination performances. Looking in greater detail at the subjects, interesting within-group differences emerge. Poor performance on the facial expression task is predicted by a low score on communicative skills tests but not on general intelligence nor on verbal intelligence skills. This suggests that poor performance on this facial expression test is not a matter of general learning skills or ease of manipulating verbal labels.

Some final caveats. The question whether facial emotions are perceived categorically is not so interesting in itself, but rather for its potential relevance to discussions on the locus of emotion perception in the cognitive architecture of the organism. Neither our present data nor previously obtained data allow inferences that generalise beyond the perception of emotions in facial expressions. Issues of cognitive or functional primitives underlying the perception of facial expressions may be connected to the notion of natural categories or prototypes. Such inferences raise interesting questions on the domain specificity of the facial expression perception mechanisms. Are emotions presented in voices through speech prosody also perceived categorically? If so, does the same mechanism sustain perception in the two modalities? Recent evidence (de Gelder & Vroomen, 1995) suggests that such might be the case, since there is a clear cross-modal effect from one modality to the other. There is increasing evidence that the perception of some emotional states is subserved by specialised cognitive and neurological circuitry (Adolphs et al., 1994). From this perspective, it is tempting to consider basic emotions, at least the cognitive ability underlying their perception, as consisting of a limited set of expressive primitives and to view CP results as providing crucial evidence. For example, Ekman (1994) argues that findings of categorical perception of facial expressions support the notion of basic emotions that would be expressive universals, invariant across cultures. Current candidates for membership of the class of basic emotions must therefore be considered on their own. Findings supporting categoricity of an emotion will need to be integrated with neurobiological, neuropsychological, and developmental data before inferences about expressive primitives can be drawn.

4. Impaired categorical perception of facial expressions in autistic adolescents[1]

4.1. INTRODUCTION

Research on the perception of facial expression in autistics over the last 10 years has suggested a face processing deficit in this population. The area that has received most attention is that of the autistics' ability to process facial expressions (e.g., Davies, Bishop, Manstead & Tantam, 1994; Hobson, 1986a, 1986b; Hobson, Ouston & Lee, 1988; Langdell, 1978). This special interest in expression perception is not surprising, given Kanner's (1943) statement that autistic children "have come into the world with the innate inability to form the usual biologically provided affective contact with people". Normally, a facial expression is recognized easily. Not only is this the case across different cultures (Ekman, 1984, 1994), but infants recognize facial expressions very early on (Meltzoff & Moore, 1977; Markham & Adams, 1992). According to Hobson (1993), autistics are impaired in those 'primary representations' that are relevant for socio-emotional and especially affective interpersonal relations. Such a view of autism would fit a perspective that supposes a biologically endowed ability for expression recognition. Etcoff and Magee (1992) sum up several lines of evidence that support this suggestion. For example, animal studies have found neurons that are selectively sensitive to expressions (Hasselmo, Rolls & Baylis, 1989; Perrett, Smith, Potter, Mistlin, Head, Milner & Jeeves, 1984), patients with brain injuries can be selectively impaired on expression recognition (Bruyer, Laterre, Seron, Feyereisen, Strypstein, Pierrard & Rectem, 1983; Etcoff, 1984; Campbell, Landis & Regard, 1986), and infants as young as 12 days old imitate facial expressions (Meltzoff & Moore, 1977).

The recognition of facial expressions is only one of the dimensions of face recognition (Bruce & Young, 1986). Facial speech analysis (lip reading), directed visual processing (for selective attention to certain aspects of the facial structure) and familiar face recognition are taken to be expression-independent processes within the face encoding system. While the data converge towards an expression recognition deficit, it is hard to evaluate the relation between an impairment in the perception of expressions, possibly caused by a deficit in emotion perception, and other, possibly more structural aspects of face encoding. A supplementary source of difficulty is that autistics

[1]Submitted for publication as: Teunisse, J.P. & de Gelder, B. Impaired categorical perception of facial expresssions in high-functioning adolescents with autism.

The authors would like to thank Petra Piree for assistance in testing the children. We are grateful to the staff and pupils of the Dr. Leo Kannerhuis, Oosterbeek, and of Basisschool De Helle, Tilburg. We are indebted to Paul Bertelson for valuable discussion.

may use different face processing strategies. A review of available studies for disentangling expression recognition from other aspects of face processing illustrates how several factors may have been masking these strategies. To begin with, some paradigms are not sensitive enough to bring out different styles of processing. An example of this is the matching task, a widely-used method in face recognition. In the simplest version of this task, subjects are asked to match photographs of facial expressions to a set of target photographs. Target and test photographs are usually not exact copies, but differ on dimensions other than expression, e.g., orientation or identity. Performance on expression matching is then compared to performance on identity matching, and in some experiments also to matching objects (Braverman, Fein, Lucci & Waterhouse, 1989) or symbols (Davies et al., 1994). Braverman et al. (1989) found that in such a task autistics made more errors on expression matching than a control group that was matched on nonverbal IQ. On identity and object matching the autistics did not differ. In a similar experiment, however, Ozonoff, Pennington & Rogers (1990) found that autistics were not only worse on expression matching, but also on identity matching and matching a face to an affect-laden situation (such as two children fighting). Only on object matching were the autistics as good as their controls. In a sorting task used in the same study, autistics were only worse in sorting expressions and not in sorting identities, but this interaction was not significant. Davies et al. (1994) studied identity matching, expression matching and symbol pattern matching in high- and low-functioning autistics. They found that high-functioning autistics were worse on all tasks, while the low-functioning autistics did not differ from their controls. Teunisse and de Gelder (1994) did not find deficits in high-functioning autistics on an expression-matching task that was part of a clinical test battery for face recognition.

In a more complex version of the matching task, the ability to generalize the affective meaning of a face to another domain, e.g., the voice, gestures, or emotional context was studied. Macdonald, Rutter, Howlin, Rios, Le Conteur, Evered & Folstein (1989) found that adult autistics made more errors than their controls in matching a facial expression to an emotional context. In addition, Bormann-Kischkel, Amorosa & von Benda (1992) found that both low- and high-functioning autistics were less able than their controls to match a vocal expression to the appropriate facial expression. However, there was no non-emotional control task in these experiments. Hobson (1986a, 1986b), who used a cross-modal task with objects as a control, found that autistics were impaired in choosing the appropriate drawings and photographs of facial expressions that go with videotaped gestures, vocalizations, and contexts. Normal performance on the non-emotional control task suggests that this impairment was not general, but specific for affective stimuli. In a replication of this experiment by Prior, Dahlstrom and Squires (1990), however, no impairments were found in autistics. On the other hand, Ozonoff et al. (1990) found that autistics were not only worse in a condition where photographs of facial expressions had to be matched to sounds with emotional intonation, but also in a non-emotional condition where sounds had to be matched with common objects, animals, and actions. This would suggest a more global perceptive deficit that is not exclusively dependent on affective processing. Van Lancker, Cornelius & Kreiman (1985) presented neutral sentences which were spoken in different emotional intonations. They had to be matched to either line-drawings representing the meaning of the sentences or to line-drawings of facial expressions that corresponded to the intonation. Older autistics made more errors than their controls on the emotional matching task, while the younger autistics were worse than their controls on the linguistic task.

A study by Hobson et al. (1988) makes it clear that performance in a matching task can be the result of different face-processing strategies. In the original matching task of expression and identity, no differences were found between autistics and mentally retarded controls. However, when parts of the face (first the mouth, then mouth-and-forehead) were blanked out, there was a greater decline in performance on expression matching for the autistics than for the controls, while this decline was the same for both groups in the identity matching task. Moreover, correlations between identity and expression matching were higher for autistics, suggesting that autistics might be processing facial expressions in a 'non-emotional' way.

A further indication that faces may be processed qualitatively differently in autistics was found in a second experiment by Hobson et al. (1988), where full photographs were presented upside-down. Although both groups made more errors in this condition, the autistics performed better than the controls on both expression matching and identity matching. This relatively good performance on inverted faces in autistics was also found in two other studies. Langdell (1978) presented familiar faces upside-down and in several masking conditions. Subjects of two age levels (10 and 14 years old respectively) were asked to name the faces. In the inverted condition, young autistics were no different from their controls, whereas older autistics had a superior recognition ability in this presentation mode. The masking conditions revealed that all autistics paid more attention to the lower half of the face than their controls. Tantam, Monagham, Nicholson & Stirling (1989) found that autistics, relative to retarded controls, made more errors in a multiple choice task on labelling expressions, while they were not different in labelling objects. However, when the facial expressions were presented upside-down, autistics, in contrast to the controls, did not drop in level of performance.

Other studies suggest that autistics are not blind to facial expressions, but that expressions are less salient to them. Weeks and Hobson (1987) found that, relative to mentally retarded controls, autistics prefer to sort photographs of faces by type of hat rather than by facial expression. Many autistics did not sort by expression at all, even if this was the only discriminant feature of the stimuli or when they were explicitly asked to do so. In a similar experiment by Bormann-Kischkel et al. (1992), low- and high-functioning autistics had to select, out of 3 cards, 2 exemplars that went together. In every task there were 2 ways of selecting: snowflakes by colour or form, faces by identity or type of wig, and faces by identity or expression. High-ability autistics preferred identity over expression, while the controls had the opposite preference. Low-ability autistics showed no preference. Autistics were not different from controls in preferring form over colour and identity over type of wig. Tantam et al. (1989) asked autistics to select the odd picture out of 4 exemplars. In one condition, a face was considered odd because it had a different expression; in the other condition a different identity was the criterion for oddness. The subjects were not told the criterion. Relative to retarded controls, autistics were worse on both tasks.

Although these experiments show that there is clearly something special in the way autistics look at facial expressions, the results are not consistent. Even when the same paradigm is used, conflicting results are found. Furthermore, there is important variability within the autistic group. Age, level of functioning, and verbal and nonverbal intelligence influence task performance. In addition to such basic variations there is another source of intra-group differences that may at least indirectly affect performance. Most autistics are in special education classes, which includes training to improve their communication skills in social situations. An important part of this training is learning to recognize facial expressions. As a result of such tutoring, many autistics, especially the high-functioning ones, may develop compensation strategies for their deficit and, as a consequence, perform well in tasks of expression recognition (de Gelder, 1987). The representations and processes sustaining compensatory recognition may be different from what is put forward in models of normal face recognition. One critical way in which compensation strategy-based expression perception would differ from its natural or primitive counterpart might be that the latter but not the former would proceed from the presence of prewired expression categories in the organism. This brings us to the paradigm used in the present study.

In the domain of speech research, the categorical perception paradigm has been extensively used to argue for basic perception categories (see Repp, 1984, for a historical overview). Etcoff and Magee (1992) adapted this paradigm to find evidence for the hypothesis that an innate mechanism for expression recognition is tuned to facial configurations presenting some basic expressions. These would be the expressions that are perceived categorically. They constructed several expression continua of line-drawings from one expression to another and found categorical perception for happiness, sadness, fear, anger and disgust. In a recent study, de Gelder, Teunisse, and Benson (in press) applied the same methodology with photo-realistic stimuli instead of drawings. They found evidence for categorical perception of emotional expressions in both adults and children.

In this paper, the categorical perception in high-functioning autistics is studied using the same materials and methodology as de Gelder et al. (in press). Three continua are used: angry-sad, angry-afraid, and happy-sad. The performance of the autistic group is compared with the results of normal adults, but also variance between autistics will be discussed by considering subgroups based on age, verbal IQ, nonverbal IQ and social IQ. The latter analysis can help us understand what factors influence task performance on expression recognition in autistics.

4.2. EXPERIMENT: THE CP TASK WITH AUTISTICS

4.2.1. Method

Subjects

Seventeen autistic subjects (13 male and 4 female) participated in this experiment. Twenty-four normal adults (12 male and 12 female; mean age 21.3 years, range 18-29) completed the angry-sad continuum, and 24 other normal adults (12 male and 12 female; mean age 20.9 years, range 18-26) completed the other two continua.

Autistic subjects were drawn from an institute for non-retarded autistic adolescents. They satisfied the diagnostic criteria for the autistic disorder according to DSM-III-R (1987). Raven's matrices (Raven, 1960) were administered as a measurement of visuo-spatial intelligence. Verbal abilities were tested with the sub-test "woordenlijst" (word list) of the Groninger Intelligentie Test (Luteijn & van der Ploeg, 1983). Social intelligence was tested with the Social Interpretation List (Vijftigschild, Berger & van Spaendonck, 1969) and WAIS Picture Arrangement. Social IQ was positively correlated with GIT-wordlist ($r = .62$, $p < 0.01$). No other correlations were significant. Table 4.1 shows the details for the autistic group.

The influence of age, verbal IQ, nonverbal IQ and social IQ was studied by dividing the autistic sample into 3 subgroups for each variable. As the population size is small, only subgroup effects that are found in all three continua are considered to have a reliable mediating influence.

The subgroups were formed as follows:

Age group: 6 younger (16;1 - 18;2), 5 middle (18;7 - 20;) and 6 older (20;7 - 24;8) subjects;

Raven group: 6 low (25 - 37), 6 middle (38 - 43) and 5 high (45 - 55) scoring subjects;

GIT group: 6 low (1 - 5), 5 middle (7 - 11) and 6 high (12 - 17) scoring subjects;

Social IQ group: 6 low (50 - 85), 5 middle (90 - 100) and 6 high (105 - 115) scoring subjects.

One male autistic subject (20;8 years old; Raven score 38; GIT score 12; Social IQ score 100) was not available for testing on the angry-afraid and the happy-sad continua, and one other male autistic subject (24;8 years old; Raven score 36; GIT score 12; Social IQ score 85) was not available for testing on the happy-sad continuum.

Four of the 17 autistics on the angry-sad continuum had a 50% identification point that fell outside the 0-10 range and were excluded from further analyses. One autistic on the angry-afraid continuum had a 50% point of 0.87. His data were used for analyses of the identification task, but as it was not possible to calculate a mean peak value, these data were not used for the discrimination analyses.

	Mean	S.D.	Range
Age	19y;5m	2y;2m	16y;1m-24y;8m
Raven raw score	40.65	7.83	25-55
GIT-wordlist raw score	8.70	4.70	1-17
Social IQ score	92.94	17.05	50-115

Table 4.1. Details of the autistic subjects (N = 17; 13 males, 4 females).

Materials

Stimuli were computer-generated black and white photographs representing a continuum of facial expressions. The continuum was created by a morphing program (Benson & Perrett, 1991; Benson, 1994). The prototype expressions were taken from a standardized set (Ekman & Friesen, 1976) and digitized. The morphing program created gradual changes from one prototype expression to the other. The result of the morph sequence was a continuum of 11 faces (2 prototype expressions and 9 intermediate faces, see Appendix A). The computer grey-scale pictures were 9.5 x 6.3 cm.

Procedure

The autistic subjects were tested individually in a quiet room at the institute. The Commodore 369SX colour monitor was placed at a distance of 1.5 meters from the subject (stimuli subtended a visual angle of 3.6 x 2.5 degrees). The experimenter saw to it that the subjects paid attention to the task.

Three expression continua were tested: angry-sad, happy-sad, and angry-afraid. After first analyzing the results of the angry-sad continuum, it was decided to adapt the step size of the ABX discrimination task from 3 to 2 steps for the happy-sad and angry-afraid continua that were tested some months later.

The experiment consisted of the ABX discrimination task and the identification task successively.

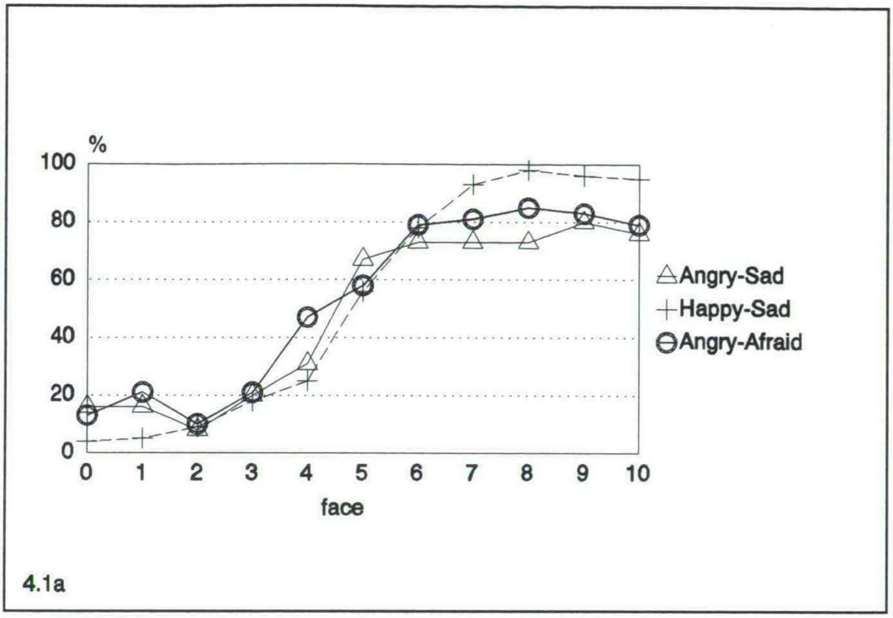
In the ABX discrimination task, 800 msec after an auditory warning signal, 3 successive pictures were shown for 1 second, separated by 1-second intervals. The first 2 pictures (A and B) differed 3 steps along the angry-sad continuum, and 2 steps along the angry-afraid and happy-sad continua. The third picture (X) was identical to A or to B. Subjects indicated which picture (A or B) was identical to picture X by pressing one of two response keys labelled A and B. The time out period for reaction was 5 seconds for autistics, and 3 seconds for normal adults. Intertrial interval was 2 seconds. Since the AB points on the angry-sad continuum differed 3 steps, 8 comparisons could be made. In the angry-afraid and happy-sad continua, 9 comparisons were made. Four combinations of every comparison were possible (ABA, ABB, BAA, BAB). Every combination was given 3 times, yielding a total of 96 randomized trials for angry-sad and 108 randomized trials for angry-afraid and happy-sad.

In the identification task, the same stimuli as in the ABX task were used, but were presented one by one. Every photograph appeared for 1 second 800 msec after the auditory warning signal. The subject indicated what expression was shown in the photograph by pressing one of two response keys. Labels of the expressions "kwaad" (angry), "verdrietig" (sad), "angst" (afraid) or "vrolijk" (happy) were placed next to the buttons. Each of the 11 stimuli was shown 3 times in random order, giving a total of 33 trials. The time-out period was 5 seconds for autistics and 3 seconds for adults. The intertrial interval was 2 seconds.

The experiment started with verbal instructions for the ABX task and a practice session consisting of 10 trials. Once the task was understood, the experimental task started.

4.2.2. Results

The total identification function (% responses) for each continuum appears in Figure 4.1a for the autistics and in Figure 4.1b for the adults. For each continuum, the identification responses of each subject were submitted to a logit transformation (Finney, 1964), which provided estimations of the 50% point and of the slope of the identification function at that point. The means of these two variables are given for each continuum in Table 4.2. To test if the identification curves have similar shapes for adults and autistics, for each continuum, a repeated-measures ANOVA with Group (autist versus adult) and Face (0 to 10) as experimental factors was carried out. A significant interaction Group x Face indicates a different shape for each group.



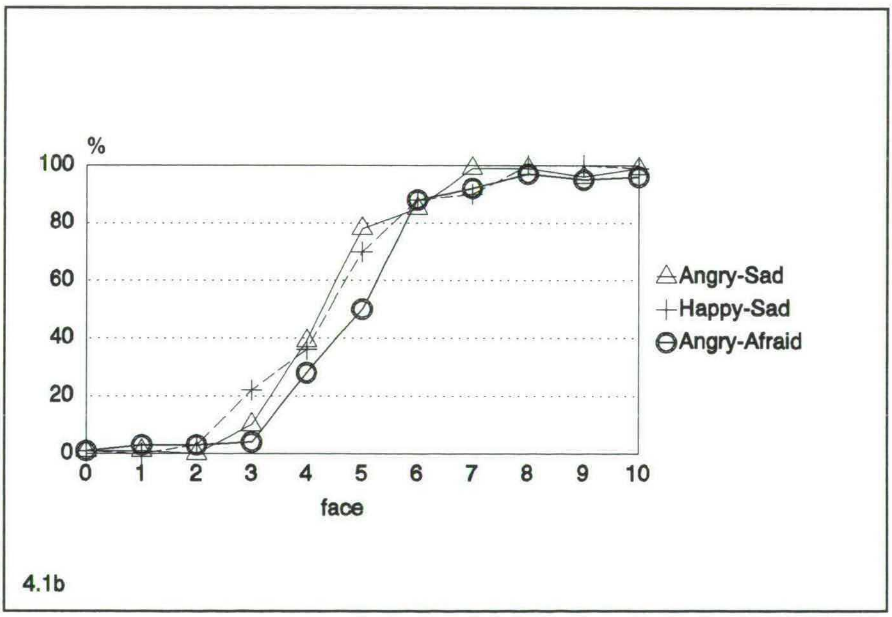
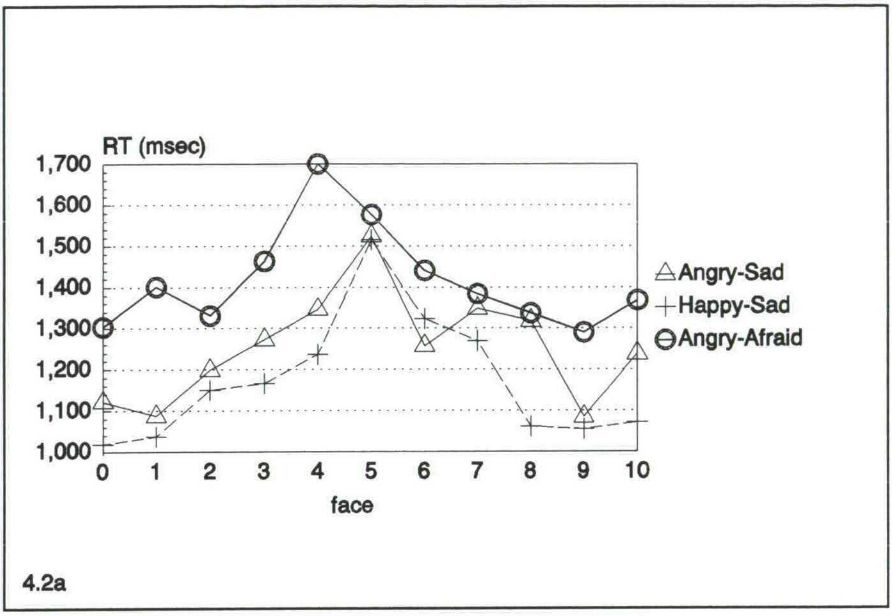


Figure 4.1. Mean response percentages for the three continua in the identification task.
a. Autistics
b. Adults



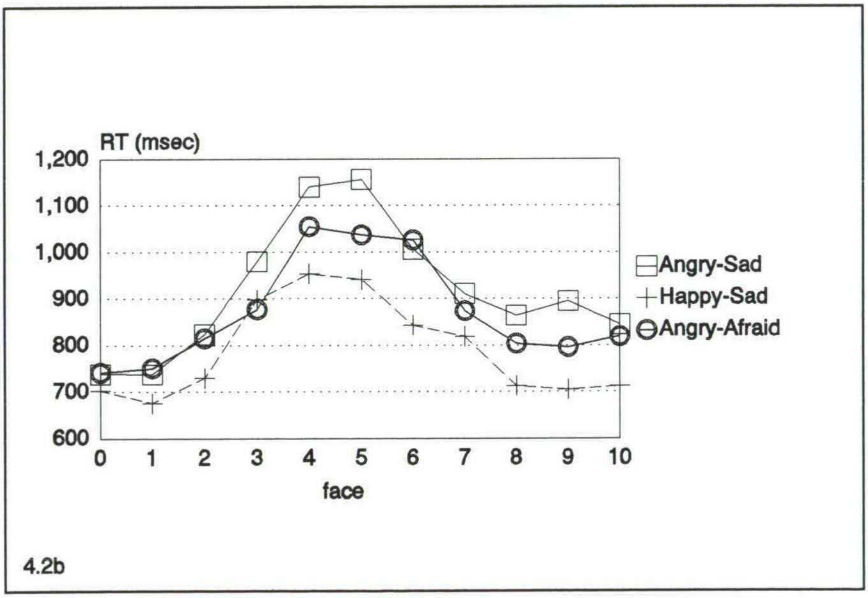


Figure 4.2. Mean reaction times for the three continua in the identification task.
a. Autistics
b. Adults

	Angry-Sad	Happy-Sad	Angry-Afraid
A. Autistics			
Identification			
50% point	4.69	4.59	4.20
Slope	35.46	55.55	46.85
Discrimination			
Peak	67.4	57.8	68.7
Non-Peak	66.9	61.0	66.1
t	.29	-1.07	.94
df	14	14	14
2-tailed p	.779	.301	.364
B. Adults			
Identification			
50% point	4.42	4.42	4.94
Slope	63.56	62.24	57.12
Discrimination			
Peak	81.1	73.5	81.7
Non-Peak	74.6	68.0	76.0
t	3.16	2.28	3.27
df	23	23	23
2-tailed p	.004	.032	.003

Table 4.2. Identification and discrimination results.

	Angry-Sad	Happy-Sad	Angry-Afraid
A. Autistics			
50%	1404	1443	1664
Rest	1221	1114	1363
t	2.19	5.31	3.38
df	16	14	15
2-tailed p	.044	.000	.004
B. Adults			
50%	1164	982	1043
Rest	866	748	837
t	5.91	7.31	6.57
df	23	23	23
2-tailed p	.000	.000	.000

Table 4.3. Mean identification reaction times for 2 photographs around the 50% identification point and all other points together.

The ABX discrimination data were compared subject-by-subject to the prediction from the identification data. The most generally agreed upon manifestation of categorical perception is the occurrence of a peak in discrimination performance around the point on the continuum at which identification reaches 50%. To account for individual differences, the discrimination data of each subject were reduced to two values, one corresponding to the predicted peak and the other to regions of the continuum on either side of the peak. For angry-sad, where the AB points used in the ABX task were 2 steps apart, each subject's 50% identification point falls into two successive AB intervals, and the peak discrimination is supposed to fall in one of these. For instance, for a subject whose 50% points is at 4.2, the peak must occur in one of the two intervals 3-5 and 4-6. We chose to consider the two intervals as containing the predicted peak. For happy-sad and angry-afraid, where 3-steps intervals were used in the ABX task, the predicted peak consisted of three AB intervals. Our test consisted of calculating two measures of discrimination performance for each subject: a 'peak performance' value which is the mean of the observed % correct responses over the peak intervals, and a 'nonpeak performance' value, which is the mean of the same % correct over the remaining intervals. Significance was assessed using the t-test.

Table 4.2 shows that adults, as predicted by the categorical perception theory, show higher peak performance in each continuum, whereas autistics do not show higher scores on the predicted peaks on any continuum.

The shape of the identification curve is different for adults than for autistics on angry-sad (interaction Group x Face: $F(10, 390) = 4.98$, $p < 0.001$) and angry-afraid ($F(10, 380) = 3.26$, $p < 0.001$). Not only was the slope on the 50% identification point less steep for autistics, but the scores on the endpoints of these continua were also less extreme (Figure 4.1). The identification curve of happy-sad was no different for either group.

RTs in both the identification and the ABX task were submitted to subject-by-subject analysis following the same principle as the correct discrimination data. For identification, the prediction for categorical perception was slower RT for the two photographs on either side of the 50% point (the "peak RTs") than for the other items. Figure 4.2 shows the RT identification functions. The results which appear in Table 4.3 support the prediction for both groups on all three continua.

For the ABX task, the prediction was shorter mean RTs for the two "peak intervals" than for "non-peak" ones. This prediction was not supported, for either autistics or adults, for any of the three continua.

There were important differences within the autistic group as the identification curves for angry-sad and angry-afraid were deviant for some autistics but not for all. Subgroup analyses revealed that only autistic subjects with a low social IQ score showed the deviant pattern (Figure 4.3). The Social subgroup x Face interaction was significant for both angry-sad ($F(20, 140) =$

2.54, $p < 0.001$) and angry-afraid ($F(20, 130) = 2.14$, $p < 0.01$).

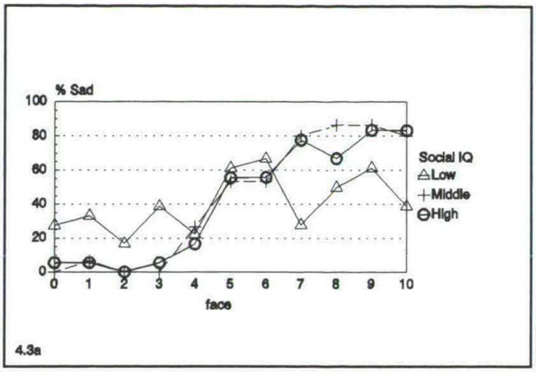
No subgroup effects were found on the happy-sad continuum, but even there, the slope of the function correlated most with social IQ (Table 4.4). These results seem to indicate that social IQ is an important mediating factor in the performance on the identification task.

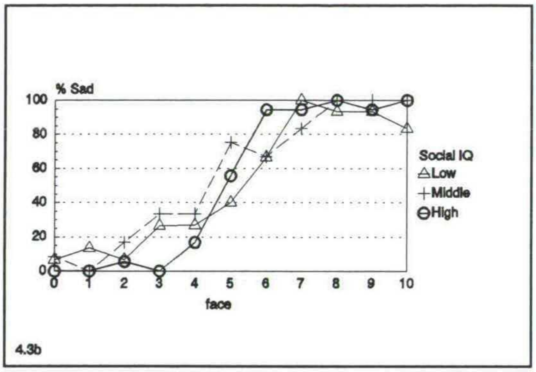
Some other subgroup effects were also found, but these were not replicated in other continua. On the angry-sad continuum, there was a small effect of age ($F(2,10) = 4.09$, $p < 0.05$) on performance in the discrimination task, with the best performance by the oldest subgroup. A GIT group x ABX Peak-performance interaction ($F(2, 12) = 5.54$, $p < 0.020$) on the angry-sad continuum suggests that only autistics with a low verbal IQ score show a higher peak performance in the discrimination task. These findings are not replicated in the other continua and will therefore not be considered here as reliable effects.

	Angry-Sad	Angry-Afraid	Happy-Sad
Age groups	-.05	-.05	.00
Nonverbal score groups	.25	.50*	.19
Verbal score groups	.50*	.32	.34
Social IQ groups	.55*	.50*	.44

* $p < 0.05$

Table 4.4. Correlations between slope of the identification function and autistic subgroups.





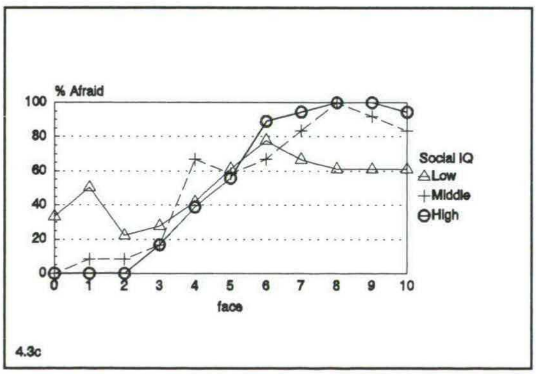


Figure 4.3c. Results of the Social IQ subgroups on the identification task.
a. on the angry-sad continuum.
b. on the happy-sad continuum.
c. on the angry-afraid continuum.

4.3. Discussion

The main goal of this study was to investigate whether autistics perceive facial expressions categorically as do normal children and adults. An ABX discrimination task and an identification task were administered to the subjects, using photo-realistic stimuli of 3 expression continua. The finding that discrimination performance in high-ability autistic adolescents was not predicted by identification performance suggests that they may not perceive facial expressions categorically. The RT results in the identification task seem to contradict this conclusion: on each continuum, autistics had slower RTs for photographs around the category boundary. However, de Gelder et al. (in press) have shown that this RT effect is probably not related to categorical perception but to a dichotomy artefact or some other general-type mechanism. In a control condition, they presented the same photographs upside-down to normal adult subjects, a manipulation that is known to distort the perception of facial expressions (Thompson, 1980; Rock, 1988). The results were similar to the present autistic data: no significant peak in the discrimination task and a slower RT around the category boundary in the identification task. The fact that the discrimination peak was found with photographs in the normal rightway-up orientation but not in the inverted mode rules out the dichotomy artefact hypothesis, which predicts that a peak will occur on any continuum. Furthermore, the fact that in the identification task a slower RT around the 50% point is found even when the photographs are presented upside-down makes it very unlikely that this peak is specific for categorical processing of emotions. These findings support the conclusion that the autistics in the present experiment did not process the facial expressions categorically.

It is interesting that the present results for the autistic subjects parallel the results of the normal subjects on inverted photographs in the study by de Gelder et al. (in press), i.e., no peak in the discrimination task and a slower RT around the 50% identification point. This parallel might indicate that in autistics, there is no qualitative difference in the processing of normal rightway-up faces and of inverted faces. Experiments with autistics on inverted faces support this suggestion; while controls show a serious decrease in recognition performance when photographs are presented upside-down, many autistics are influenced to a much lesser extent by inversion (Langdell, 1978; Hobson et al., 1988; Tantam et al., 1989; Teunisse & de Gelder, submitted-b). In normal subjects, the processing style of inverted faces is qualitatively different from that of normal faces (Diamond & Carey, 1986). Recognition of facial identity and probably also of facial expression depends heavily on the configural information of the face. This configural information is less accessible when a face is presented upside-down. The finding that many autistics, particularly those with low social IQ scores (Teunisse & de Gelder, submitted-b), do not show the usual drop in recognition performance suggests that they might use the configural information of a face to a much lesser extent. This might also explain the present findings, since it is very likely that categorical perception of expressions depends on configural information as well (de Gelder, Vroomen & Popelier, 1996).

The robustness of the findings that emotional disorders in general and facial expression recognition in particular are impaired in autistic individuals contrasts with the increasing complexity of the behavioral and neurobiological findings. Clearly, one-factor approaches like the so-called theory of mind explanations, may appear ill-suited to respond to this situation. Moreover, another dimension related to the ability of high-functioning individuals to benefit from behavioral adjustment training and from living in adaptive environments must be added to the complexity arising from the multiple facets of the autistic impairments (Schreibman, in Lewin, 1995). Based on this ability, compensation strategies are acquired.

This is the other aspect brought out in the present data. An interesting finding in the present experiment is that autistics with a low social IQ score showed a deviant pattern in the identification task on at least 2 expression continua; they had a poor recognition score for the prototypical expressions on the extremes of the expression continuum. In contrast, the autistics with higher social intelligence were very able to recognize emotional expressions, even though their recognition was not based on categorical perception. This is strong support for the suggestion that they use compensatory strategies, which might explain the sometimes confusing results in studies of expression recognition in autistics. The present findings show that one should not conclude too quickly on the basis of good test results that autistics have no impairments in the perception of facial expressions (see also, de Gelder, 1987). Compensatory strategies may have been camouflaging the perception deficit. Most autistics nowadays get explicit training in understanding social situations and facial expressions and this may not only improve their social IQ scores (Berger, van Spaendonck, Horstink, Buytenhuijs, Lammers & Cools, 1993), but may also help them develop compensatory strategies to handle their handicap. The fact that this training leads to a better intellectual understanding of social situations in some autistics does not automatically mean that they can successfully apply this knowledge in daily life (de Gelder, 1987). Even autistics with a high cognitive level show maladaptive behaviour in social situations in the real world (Freeman, Rahbar, Ritvo, Bice, Yokota & Ritvo, 1991; Rumsey, 1985). Theoretical understanding of social situations does not guarantee empathic understanding. According to Hobson (1993), it is this inability for empathic understanding of the thoughts and feelings of other people that is the essence of autism. The present finding that autistics show an absence of categorical perception of facial expressions may very well be related to this deficit in empathic perception. Faces are perceived as affectively neutral stimuli, and only by the use of compensatory strategies may they manage to understand, although only theoretically, the significance and meaning of an emotional expression.

5. Inversion and composite effects in autistic adolescents[1]

5.1. INTRODUCTION

One of the most intriguing findings in the study of face perception in autistics is their relatively good performance on tasks with inverted photographs of faces. This performance was observed across different experimental paradigms. Langdell (1978) found that autistic adolescents were superior to normal and subnormal controls on a task where they had to recognize and name inverted faces of peers. Younger autistics were not different from their controls. Hobson, Ouston and Lee (1988) used a task in which inverted photographs of unfamiliar faces had to be matched on identity and emotional expression. Autistic adolescents were better than retarded controls in both conditions. Tantam, Monagham, Nicholson, and Stirling (1989) found that autistic children were as accurate in labelling photographs of emotional expressions in the inverted mode as in the upright mode, whereas a retarded control group, who performed at the same level as the autistics in the inverted condition, was more accurate in labelling the upright photographs.

Not only were the paradigms in these studies different, but also the focus of the interpretation of the inversion effect. Langdell (1978) and Hobson et al. (1988) consider the better performance of the autistics in the inverted condition relative to the controls as an inversion effect, while Tantam et al. (1989) speak of an inversion effect when the performance in the inverted condition is good relative to the performance of the same subjects in the upright condition. When the results in the inverted condition in the study by Hobson et al. (1988) are compared to performance of the same subjects on upright photographs, the autistics make significantly more errors on the inverted photographs. The same is true for the findings of Langdell (1978): also in this experiment, recognition in the inverted condition was more difficult than in the upright condition, where recognition for all subjects was at ceiling. In the study by Tantam et al. (1989), the autistics were not better on inverted photographs than their controls. Furthermore, the absence in this study of a difference in performance between inverted and normal orientation in autistics may be the result of a floor effect.

In the numerous studies with normal adults, the inversion effect is

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[1]Submitted for publication as: Teunisse, J.P. & de Gelder, B. Inversion and composite effects in normals and high-functioning adolescents with autism.

The authors would like to thank Petra Piree for assistance in testing the children. We are grateful to the staff and pupils of the Dr. Leo Kannerhuis, Oosterbeek, and of Basisschool De Helle, Tilburg. We are indebted to Paul Bertelson and Hans Berger for valuable discussion.

defined as the difference in performance between upright and inverted photographs of faces (see Valentine, 1988, for a review). In most experiments, the inversion effect on faces is compared to effects of inversion on other classes of stimuli. It appears that faces, compared to other stimuli, are disproportionately sensitive to inversion (e.g., Dallett, Wilcox & D'Andrea, 1968; Yin, 1969). Diamond and Carey (1986, p. 116) suggest that there are some critical conditions that have to be met for a large inversion effect. In the first place, the stimulus must be member of a class with a shared configuration. Secondly, these members should be identifiable on the basis of second-order relational features (distinctive relations among the elements of this configuration). And finally, the subjects must be experts on the stimulus class. They found that these criteria were met with face stimuli, but also when dog experts had to recognize inverted photographs of dogs (Diamond & Carey, 1986).

The most standard experimental paradigm in this field is the old-new recognition task of identity. Subjects are asked to look at a series of photographs of faces and try to remember them. After inspection, the recognition series is presented and subjects are asked to indicate which picture had been shown in the inspection series. The inversion effect is very robust. It is found in recognition tasks of both familiar faces (e.g., Yarmey, 1971; Rock, 1974) and unfamiliar faces (e.g., Yin, 1969; Scapinello & Yarmey, 1970; Phillips & Rawles, 1979). It is found when the presentation mode of inspection and recognition series is the same (both inverted or upright) (Yin, 1969), and when the inspection series of the inverted recognition series is upright (Scapinello & Yarmey, 1970; Valentine & Bruce, 1986; Yarmey, 1971). The effect is found in blocked (Valentine & Bruce, 1986) and in mixed presentation of the conditions (e.g., Diamond & Carey, 1986, Scapinello & Yarmey, 1970). Even a mixed inspection series leads to an inversion effect (Valentine & Bruce, 1986). Besides the old-new test procedure, a forced-choice test procedure is also effective (Diamond & Carey, 1986; Yin, 1969). Photographs on the inspection and recognition list need not be identical to produce the inversion effect (Valentine & Bruce, 1986), which indicates that it is the identity of the face and not the specific photograph that is crucial for a large inversion effect. Recognition of facial expression is also strongly affected by inversion, as is demonstrated by the 'Margaret Thatcher illusion' (Thompson, 1980). When the eyes and mouth are inverted in a normal upright face, the expression becomes gruesome, but when this doctored face is presented upside-down the gruesomeness is no longer perceived.

There is some evidence that the inversion effect is not found in a matching task (Valentine, 1986; Bruyer & Velge, 1981). Valentine (1988) suggests that a memory component must therefore be involved to find the effect. However, the results of Hobson et al. (1988), where both autistic and retarded subjects made more errors when faces were inverted in matching tasks of identity and expression, are not consistent with this view. Task difficulty might be of more importance. For normal adults, a matching task might be too simple to find an effect of inversion. For groups with mental impairments, however, matching faces that are not identical might be difficult enough to be sensible for inversion. Developmental studies show that matching tasks of faces that differ in view, facial expression, clothing, or lighting condition, are difficult for normal children too (e.g., Benton & van Allen, 1973; Diamond & Carey, 1977). An interaction between task difficulty and orientation was indeed suggested by the results of Valentine and Bruce (1988), with larger inversion effects for the more demanding tasks.

Floor effects that possibly biased the Tantam et al. study (1989) may also have affected studies of the inversion effect with children. Carey and Diamond (1977) and Carey, Diamond, and Woods (1980) found exactly the same pattern of results in a study with children as Tantam et al. (1989) found with autistics; upside-down faces were recognized as well as upright faces. Flin (1985) however, showed that this was due to floor effects. When she reduced task demands by decreasing the number of test items and prolonging the exposure duration of the inspection stimuli, she found that even 7-year-olds were more accurate on upright faces than on inverted faces. Furthermore, she found that recognition of inverted faces improved between 7 and 16 years of age, but not as much as the recognition of upright faces. This confirms that experience with the stimulus is important for the inversion effect.

The results of the studies with autistics suggest that they improve more on the recognition of inverted faces when they grow older than other people. The relatively good performance on the inverted photographs in the studies by Langdell (1978) and Hobson et al. (1988) was found for adolescent autistics. Younger autistics were not superior in this condition to their controls (Langdell, 1978; Tantam et al., 1989).

Two experiments were carried out in the present study. In Experiment 1, the hypothesis was that the inversion effect found by Tantam et al. (1989) might have been influenced by floor effects and that autistics will show an inversion effect under different task demands. To reduce the likelihood of floor effects in our study, the inversion effect of faces in high-functioning autistics was explored with a relatively easy recognition task. A two-alternative forced-choice test for recognition was presented directly after each inspection item, instead of first learning an inspection list and then testing. This paradigm reduces memory demands, and therefore autistic subjects and children have a better chance of showing effects. If autistics still did not show a decline in performance on inverted faces and/or a higher recognition accuracy on inverted faces than normal adults or children, the claim that autistics do not show an inversion effect would receive stronger support. In the second experiment, a multiple choice version of the composite task developed by Young, Hellawell, and Hay (1987) was administered to study in more detail the processing style of autistic subjects that might be responsible for the deviant results on inversion tasks. Good performance on the inversion tasks might indicate that autistic adolescents process faces more analytically and/or encode faces less configurally than other people, as configural encoding may be a major condition for finding the inversion effect (Diamond & Carey, 1986). On a task that depends heavily on configural encoding, like in the composite task, this deviant processing style might show. The influence of certain characteristics of the autistics on performance was taken into account by analyzing age and IQ factors in both experiments.

5.2. EXPERIMENT 1: THE INVERSION TASK

5.2.1. Method

Subjects

The subjects were 17 autistics, 24 normal children, and 24 normal adults. The normal children (12 males and 12 females) were 9 and 10 years old. They attended primary school in Tilburg. The normal adults (12 males and 12 females; mean age 23;1 years) were undergraduate students at Tilburg University.

The autistic subjects (13 males and 4 females) were drawn from an institute for non-retarded autistic adolescents, the Leo Kannerhuis in Oosterbeek. They satisfied the diagnostic criteria for the autistic disorder according to DSM-III-R (1987). Raven's matrices (Raven, 1960) were administered as a measurement of visuo-spatial intelligence. Verbal abilities were tested with the sub-test "woordenlijst" (wordlist) of the Groninger Intelligentie Test (Luteijn & van der Ploeg, 1983). Social intelligence was tested with the Social Interpretation List (Vijftigschild, Berger & van Spaendonck, 1969) and the WAIS Picture Arrangement. Social IQ was positively correlated with GIT-wordlist ($r = .62$, $p < 0.01$). No other correlations were significant. The details for the autistic group are presented in Table 5.1.

	Mean	S.D.	Range
Age	19y;5m	2y;2m	16y;1m-24y;8m
Raven raw score	40.65	7.83	25-55
GIT-wordlist raw score	8.70	4.70	1-17
Social IQ score	92.94	17.05	50-115

Table 5.1. Details of the autistic subjects (N = 17; 13 males, 4 females).

In order to analyze the influence of age, verbal IQ, nonverbal IQ and social IQ, the autistic sample was divided into several subgroups. The four subgroups were formed as follows:
Age group: 6 younger (16;1 - 18;2), 5 middle (18;7 - 20;) and 6 older (20;7 - 24;8) subjects;
Raven group: 6 low (25 - 37), 6 middle (38 - 43) and 5 high (45 - 55) scoring subjects;
GIT group: 6 low (1 - 5), 5 middle (7 - 11) and 6 high (12 - 17) scoring subjects;
Social IQ group: 6 low (50 - 85), 5 middle (90 - 100) and 6 high (105 - 115) scoring subjects.

Stimuli

Forty-two adult faces (26 females and 16 males) and 32 pairs of shoes were photographed with a Canon Still Video Camera RC-560 on a Video Floppy Disc VF-50, in frontal and 3/4 orientation. These photographs were then prepared as greyscale pictures with an image processing and production program (Aldus PhotoStyler) for presentation on a monitor. For every trial, 1 photograph in frontal view was used as target stimulus, and 2 photographs in 3/4 view for test stimuli. Pairs of faces were put together on the basis of comparable hair style. The stimuli were presented in normal and in inverted orientation (see Appendix B).

Procedure

Pilot studies revealed that most of the children performed at chance level when inspection time of the first stimulus (1 second) and the time out period (3 seconds) were the same as for adults. Therefore these were prolonged for the children. Because we learned from comparable tasks that the autistic adolescents perform at about the same level as 10-year-old children, these changes were made for the autistics as well.

Adult subjects were tested in a sound-attenuated test cabin in the laboratory. The distance to the monitor was 1.5 meters. The experimenter was outside the cabin and had contact with the subject via an intercom. Before starting the experiment, the subjects read the instructions for the task, and then were given a short training with 8 (4 upright and 4 inverted) randomized test trials. Autistics and children were tested in a quiet room at the institute or school. The experimenter was in the same room as the subject during the entire experiment. Instructions were given verbally and explained with the help of photographs. Then the 8 test trails were administered.

Following the training block, every subject completed 4 experimental blocks of randomized trials. One condition was tested in every block: Face/Upright (21 trials), Face/Inverted (21 trials), Shoe/Upright (16 trials), and Shoe/Inverted (16 trials). The order was counterbalanced within each group. The same test pairs were used in the normal and in the inverted condition, but the photographs were reversed in half of the trials.

Five hundred msec after an auditory warning signal, the first stimulus, the target photograph in frontal view, was shown (1 second for adults, 3 seconds for autistics and children). After a 2-second interval, the second stimulus, consisting of 2 photographs in 3/4 view labelled "A" and "B", was shown. Subjects were instructed to indicate as rapidly as possible which photograph depicted the same face or shoe as in stimulus 1, by pressing one of the two response buttons (also labelled "A" and "B"). The stimuli disappeared when a response was given or when the time out period was exceeded (3 seconds for adults, 5 seconds for autistics and children). The intertrial interval was 3 seconds.

5.2.2. Results

Results were analyzed for correct responses (Figure 5.1a) and for RT of correct responses (Figure 5.1b). Subjects with a z-score below 1.65 (60% correct) were supposed to respond at chance level and were excluded from analyses. One male autistic subject [16;4 years old (youngest subgroup); Raven score 45 (high); GIT score 1 (low); Social IQ score 50 (low)] was excluded for this reason.

The results of the children and adults are described first. A separate analysis for each group was carried out with a repeated measures ANOVA using Orientation (upright versus inverted) and Type of Stimulus (face versus shoe) as within-subject factors. Group comparisons were made with a repeated measures ANOVA using the same within-subject factors, and Group (adult versus child) as a between-subject factor. Then the results of the autistics are described. First, the autistics were analyzed separately as a group, then they were compared to both the adults and the children, with the same statistical tests as mentioned before. Finally, autistic subgroup results were analyzed with a repeated measures ANOVA using Subgroup (low, middle, high) as a between-subject factor and the same within-subject factors as before.

Adults versus children

The inversion effect (more errors in the inverted relative to the upright mode) in accurateness was only found for faces and not for shoes, both for adults [interaction Orientation x Type of Stimulus: $F(1, 15) = 18.20$, $p < 0.001$] and for children [$F(1, 23) = 4.52$, $p < 0.05$]. Children made more errors on faces than adults [interaction Group x Type of Stimulus: $F(1, 38) = 11.35$, $p < 0.005$].

The same Orientation x Type of Stimulus interaction was also found in RTs; this interaction was significant for adults [$F(1, 15) = 5.26$, $p < 0.05$] and a trend for children [$F(1, 23) = 3.29$, $p < 0.09$]. Children were slower on all stimuli [$F(1, 38) = 62.79$, $p < 0.001$], had a larger Type of Stimulus effect [interaction Group x Type of Stimulus: $F(1, 38) = 18.30$, $p < 0.001$], and a larger Orientation effect [interaction Group x Orientation: $F(1, 38) =$

4.95, $p < 0.05$] than adults.

Autistics versus adults and children

Most importantly, like adults and children, autistics showed an inversion effect for faces and not for shoes [interaction Orientation x Type of Stimulus: $F(1, 15) = 12.00$, $p < 0.005$]. They made more errors on faces than on shoes [$F(1, 15) = 41.98$, $p < 0.001$]. There were no group differences between autistics and children on accuracy. The difference in accuracy between shoes and faces was larger for autistics than for adults [interaction Group x Type of Stimulus: $F(1, 30) = 8.06$, $p < 0.01$].

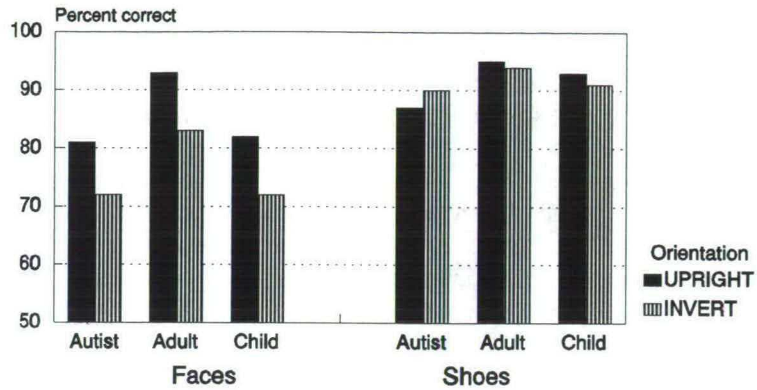
Autistics were also very similar to children in their RT pattern; there were no significant group differences. Compared to adults, autistics were slower [$F(1, 30) = 78.11$, $p < 0.001$], and also showed a larger difference in RT between faces and shoes [interaction Group x Type of Stimulus: $F(1, 30) = 15.03$, $p < 0.001$]. The important Orientation x Type of Stimulus interaction was significant for the autistics too [$F(1, 15) = 4.80$, $p < 0.05$]; the effect of inversion was larger for faces than for shoes (Figure 5.1b).

Autistic subgroups

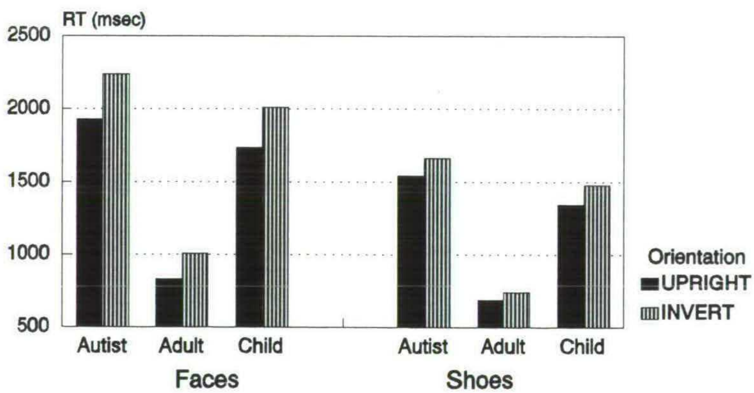
Accuracy on this task was correlated with social IQ ($r = .62$, $p < 0.05$). Significant correlations of social IQ with the two upright conditions but not with the inverted conditions suggest that autistic subjects with a higher social IQ were specifically more accurate in recognising upright stimuli. These findings were represented in the subgroup analyses as trends: lower Social IQ groups made more errors [$F(2, 13) = 3.51$, $p < 0.06$], and the inversion effect was larger for the higher Social IQ groups [$F(2, 13) = 3.37$, $p < 0.07$] (Figure 5.2a). The subject that was excluded from analyses (his score was 58% correct) belonged to the low Social IQ group. When his data were included in the analyses both trends became significant.

The RT pattern was also different for the Social IQ groups [$F(2, 13) = 4.97$, $p < 0.05$]: the inversion effect was larger for faces than for shoes in the higher Social IQ groups but not in the low Social IQ group (Figure 5.2b).

No other subgroup analyses were significant.

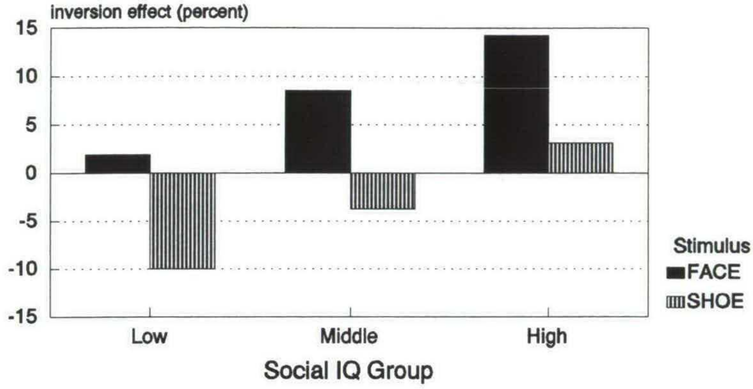


5.1a

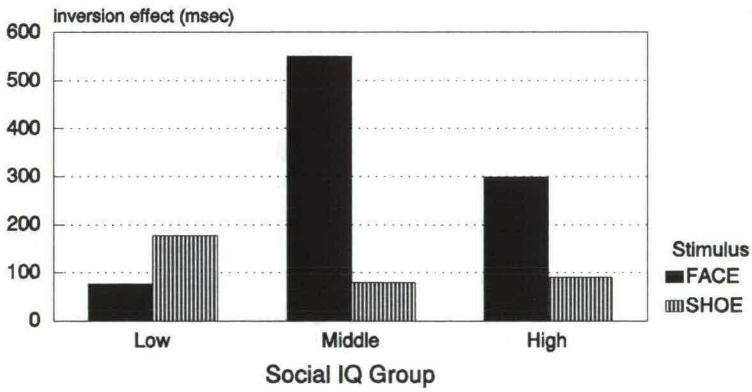


5.1b

Figure 5.1. Experiment 1: Inversion task.
a. Mean percentage correct scores of the autistic, adult and children groups.
b. Mean RT scores of the autistic, adult and children groups.



5.2a



5.2b

Figure 5.2. Experiment 1: Inversion effect for the Social IQ groups (upright condition minus inverted condition).

a. The inversion effect on accuracy scores.

b. The inversion effect on RT scores.

5.2.3. Discussion

The first experiment was conducted to determine whether the previous findings that autistic subjects show no inversion effect for faces (Langdell, 1978; Hobson et al., 1988; Tantam et al., 1989) could be replicated with reduced task demands. It was found that this was not the case. The performance of the autistic subjects was very similar to that of normal children in this task. They made more errors and were slower in responding than adults, but the response pattern was not different. Thus, in contrast to the studies by Hobson et al. (1988) and Langdell (1978), the autistics in this experiment were not superior to the controls in recognising upside-down faces, nor did the finding of Tantam et al. (1989) confirm that autistic subjects were as accurate on inverted faces as on upright faces. Like the normal subjects, they recognized upright faces more accurately and faster than inverted faces. Furthermore, for the autistics the inversion effect was also larger for faces than for shoes.

In most studies, the inversion effect is smaller for children than for adults, but this is not the case in the present study. It must be noted, however, that exposure times of the stimuli were prolonged for children and autistic subjects. Although both groups still made more errors than the adult group, it is conceivable that the prolonged exposure time allows the inversion effect to emerge to the same extent in children and autistic adolescents as in adults.

These results show that a normal inversion effect is found with most high-ability autistic adolescents when the task demands in a recognition task for unfamiliar faces are reduced, which suggests that the findings of Tantam et al. (1989) may be due to floor effects. However, there are also indications in the present study that at least some autistics do not profit from upright presentation of the stimuli. Accuracy in this mode of presentation was correlated with social IQ in the autistic group. The absence of an inversion effect in the low social IQ group cannot be attributed to a floor effect, since they scored nearly 70 percent correct in both the upright and the inverted condition. Therefore, the present results do not replicate the result that autistics are *better* in recognising inverted faces as is suggested by the studies by Langdell (1978) and Hobson et al. (1988), but that autistics with a low social IQ are *worse* in recognising normal upright faces. Impaired recognition of unfamiliar faces in autistics was also reported in other studies (de Gelder, Vroomen & van der Heide, 1991; Boucher & Lewis, 1992). However, this cannot explain why Langdell (1978) and Hobson et al. (1988) found superior performance of autistic subjects relative to their controls on inverted photographs of faces. Moreover, there are no indications that autistics are impaired on familiar face recognition. For example, in Langdell's study, all familiar faces that had to be identified were recognized in the normal upright orientation. A possible explanation might be that some autistics encode faces in a qualitatively different way that is less sensitive to inversion. This other processing style is less efficient when new, unfamiliar faces have to be encoded, but is accurate enough to perform well on familiar face recognition tasks or on the tasks of Langdell (1978) and Hobson et al. (1988). What then, might this other face processing style be?

If we follow Diamond and Carey (1986), the remarkable results with inverted photographs in previous studies suggest that autistics rely less on configural information in face encoding. Our results suggest that this might be particularly true for autistic subjects with low social intelligence. If this subgroup of autistics indeed encode faces in a nonconfigural way, then other tasks where configural information is critical should also show a deviant response pattern. Young et al. (1987) developed a task in which they fused top and bottom halves of different familiar faces to form new facial configuration. Subjects were then asked to name the upper part of these composite faces. They found that recognition is more impaired when the top and bottom halves were aligned to form a new configuration than when they were not, but only when the stimuli were presented upright. This 'composite effect' was also found with unfamiliar faces, both in the same paradigm (Young et al., 1987) and in a matching task paradigm (Hole, 1994). In a recent study, Carey and Diamond (1994) obtained the composite effect for 6- and 10-year-old children.

In Experiment 2 an adapted version of the composite task was administered to determine if autistic subjects, especially those with low social IQ scores, are less affected by manipulations of the facial configuration. As in Experiment 1, memory demands were reduced by presenting a two-alternative forced-choice test directly after each target stimulus. Unfamiliar faces in 3/4 view were used for target stimuli.

5.3. Experiment 2: The composite task

5.3.1. Method

Subjects

The same autistics and children who participated in Experiment 1 completed the task. There were at least 2 and at most 7 days between Experiments 1 and 2 for each subject of these groups. For the adult group, 24 other undergraduates (12 females and 12 males; mean age 22;4 years) were tested.

Stimuli

Still video photographs of faces in frontal view were used to prepare the composite stimuli. These faces were split into top and bottom halves using the image processing and production program 'Aldus PhotoStyler'. Test stimuli were aligned and non-aligned composites of top and bottom halves of different faces, in inverted and upright orientation (see Appendix C). The target faces were upright and inverted photographs of the same individuals in 3/4 view.

Procedure

Inspection time of the first stimulus and time out period were longer for children and autistics than for adults for reasons given in Experiment 1.

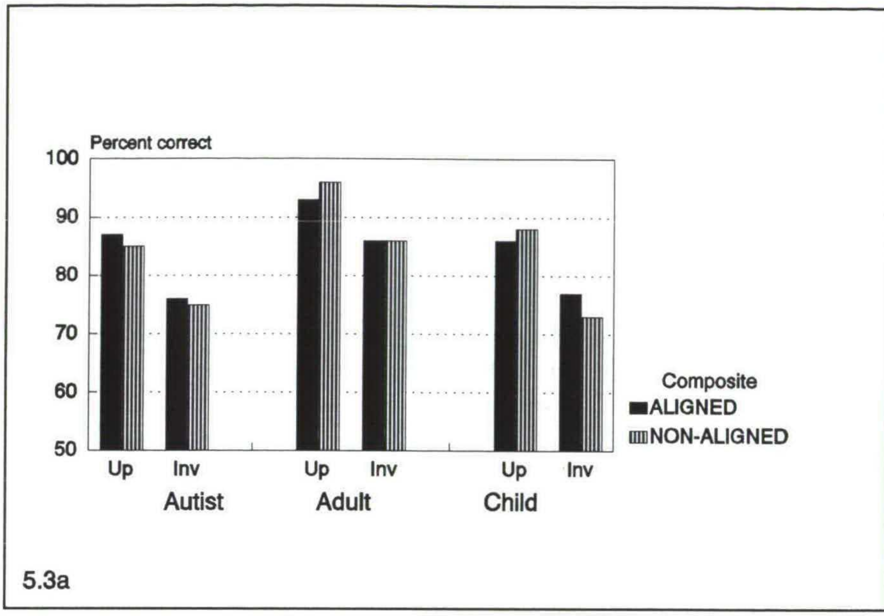
Subjects were tested in the same circumstances and with the same equipment as in Experiment 1. At the beginning of the experiment, adults received written instructions. Children and autistics were verbally instructed with the use of photographs of the stimuli. Four experimental blocks of 20 randomized trials were administered. The conditions were Upright/Aligned, Upright/Non-aligned, Inverted/Aligned, and Inverted/Non-aligned. The conditions were counterbalanced within each group. Before every experimental block, a training block of 9 randomized trials for that condition was given.

Five hundred msec after the audio warning signal the first stimulus, a photograph of the target face in 3/4 view, was presented on the monitor for 1 (adults) or 3 (children and autistics) seconds. After an interstimulus interval of 3 seconds the two alternatives were shown: the top half of the target face and the top half of a distracter face, each in combination with the same bottom half of a third face. The alternatives were labelled "A" and "B"; the task was to indicate as quickly as possible which of the 2 top halves belonged to the target face by pressing one of 2 buttons (also labelled "A" and "B"). The stimulus disappeared when a response was given (3 seconds for adults, 5 seconds for autistics and children). The intertrial interval was 3 seconds.

5.3.2. Results

The results were analyzed for correct responses (Figure 5.3a) and for RT of correct responses (Figure 5.3b). It was assumed that subjects with a z-score below 1.65 (58% correct) had responded at chance level, and they were excluded from analyses. One male autistic subject (19;8 years old (middle subgroup); Raven score 37 (low); GIT score 4 (low); Social IQ score 95 (middle)) was excluded for this reason.

The same analyses as in Experiment 1 were carried out, but this time using Orientation (upright versus inverted) and Composite (aligned versus non-aligned) as within-subject factors.



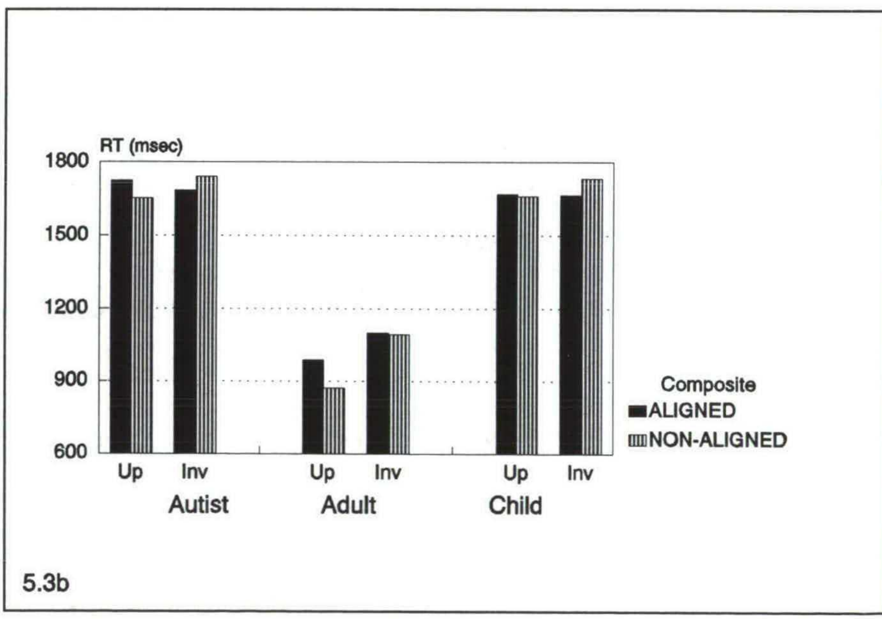


Figure 5.3. Experiment 2: Composite task.
a. Mean percentage correct scores of the autistic, adult and children groups.
b. Mean RT scores of the autistic, adult and children groups.

Adults versus children

The composite effect is defined by a significant interaction of Composite (aligned or non-aligned) with Orientation (upright or inverted), which consists of better performance on non-aligned relative to aligned photographs, but only in the upright condition. Although this interaction was significant in the overall analyses of children and adults [$F(1, 46) = 6.08$, $p < 0.05$], it was not significant in separate analyses for adults [$F(1, 23) = 2.04$, $p > 0.1$] and just failed to reach significance in children [$F(1, 23) = 4.05$, $p < 0.06$]. Children made more errors than adults [$F(1, 46) = 31.43$, $p < 0.001$], and both adults [$F(1, 23) = 73.69$, $p < 0.001$] and children [$F(1, 23) = 53.71$, $p < 0.001$] made more errors on inverted stimuli.

In the RT analyses, the composite effect was found for the adults [interaction Composite x Orientation: $F(1, 23) = 6.12$, $p < 0.05$], but for the children no RT effects were found. For adults, main effects were also significant: upright stimuli were faster than inverted stimuli [$F(1, 23) = 62.06$, $p < 0.001$], and non-aligned stimuli were faster than aligned stimuli [$F(1, 23) = 5.98$, $p < 0.05$]. This difference between adults and children in main effects was reflected in significant interactions in the overall analyses of Group with Orientation [$F(1, 46) = 7.50$, $p < 0.01$] and of Group with Composite [$F(1, 46) = 4.77$, $p < 0.05$]. Children were slower than adults [$F(1, 46) = 36.85$, $p < 0.001$].

Autistics versus adults and children

Autistics were not different from the children in both accuracy and RTs, but they did not show a trend for the composite effect like the children did. Autistics made more errors than adults [$F(1, 38) = 14.50$, $p < 0.001$], and they were more accurate in the upright than in the inverted condition [$F(1, 15) = 15.10$, $p < 0.001$].

Like children, autistics showed no RT effects. Adults were faster than autistics [$F(1, 38) = 28.73$, $p < 0.001$], and the Group x Orientation interaction [$F(1, 38) = 4.96$, $p < 0.05$] showed that only adults were faster on upright stimuli. No other group effects were significant.

Autistic subgroups

The prediction on the basis of the results of Experiment 1 that impaired configural processing is specific for autistic subjects with a low social IQ score, was not confirmed in a significant Social IQ group x Composite x Orientation interaction, although task performance was correlated with Social IQ ($r = .55$, $p < 0.05$). Task performance was also correlated with age ($r = .58$, $p < 0.05$), which was expressed in the subgroup analyses in a significant difference between Age groups [$F(2, 13) = 4.10$, $p < 0.05$]: the oldest group was more accurate on this task. The GIT score was only correlated with both inverted conditions (Inverted/Aligned: $r = .53$, $p < 0.05$; Inverted/Non-aligned: $r = .54$, $p < 0.05$) and not with the upright conditions. In the subgroup analysis, this was represented in a significant GIT group x Orientation interaction [$F(2, 13) = 3.93$, $p < 0.05$]. There was also a main GIT group effect [$F(2, 13) = 4.36$, $p < 0.05$]: the mean percentage correct was lowest for the lowest GIT group.

Furthermore, in the RT data, no indications were found that impaired configural processing was related to social IQ. There was, however, a significant interaction of Raven group x Orientation x Composite [$F(2, 13) = 5.52$, $p < 0.02$], which suggests that the composite effect is only absent in the low Raven group (Figure 5.4). There was also an Age group x Composite interaction [$F(2, 13) = 4.50$, $p < 0.05$]; the oldest group was fastest on non-aligned composites and the youngest group was fastest on aligned composites.

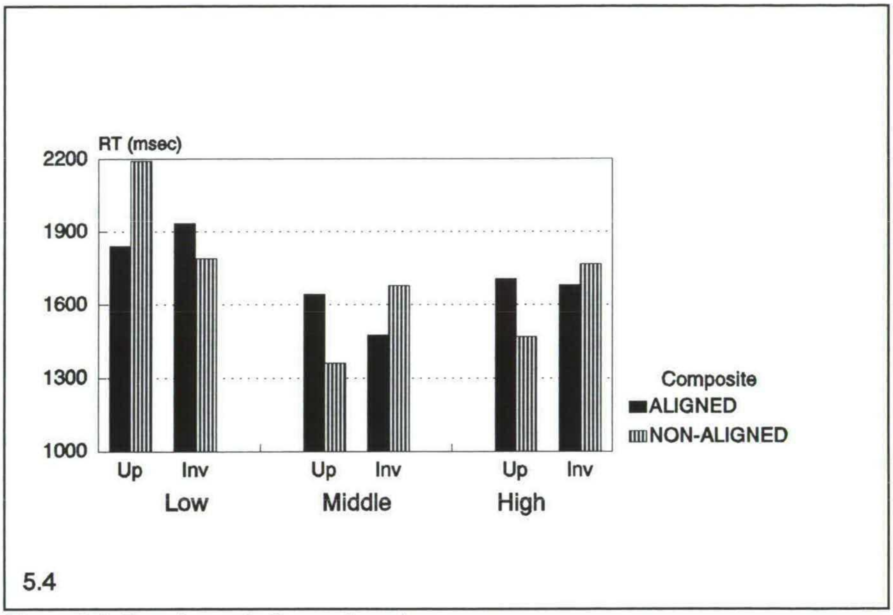


Figure 5.4. Experiment 2: Composite task.
Mean RT scores of the Nonverbal IQ groups.

5.3.3. Discussion

Experiment 2 was conducted to determine whether the deviant performance on inversion tasks could be attributed to a nonconfigural processing style in at least some autistic adolescents. The results of Experiment 1 led to the hypothesis that configural processing is negatively correlated with social IQ score. This was studied with a modified version of the composite task of Young et al. (1987).

To begin with, also in this modified paradigm, the RT data of the normal adults replicated the findings of Young et al. (1987) and Carey and

Diamond (1994): non-aligned composites were recognized faster but not significantly better than aligned composites in the upright presentation mode. Furthermore, for adults the inversion effect was found both in the accuracy and the RT data, which is again consistent with the earlier studies. The results of the normal children were also compatible with the findings of the Carey and Diamond (1994) study with 10-year-old children, although the composite effect in the present experiment just failed to reach significance. The composite and the inversion effect were found only in the accuracy data.

As in Experiment 1, the performance of the autistic subjects was very similar to the normal children's performance. The only difference between the autistic subjects and the children was that the autistics showed no trend for a composite effect. For the autistics, like the children, the inversion effect was found in the accuracy data only. The prediction that a nonconfigural processing style was shown selectively by the subgroup of autistics with a low social IQ was not confirmed. Performance was correlated with social IQ score, but also with age and verbal IQ, suggesting that a more general level of functioning was responsible for this correlation. At first glance, it is surprising that there was no interaction of social IQ with inversion in this task; the autistic subjects with a low social IQ score also made more errors on inverted than on upright stimuli. The RT data, however, showed that there was a trend that autistics with a low social IQ were faster on inverted stimuli than on upright stimuli. This suggests a trade-off for this group: they made more errors on the inverted stimuli because they responded faster on these stimuli. In contrast, the high Social IQ group made more errors on inverted stimuli even though they responded more slowly. So, although in this task there are also some indications that autistics with a low social IQ use different processing strategies with inverted stimuli, social IQ does not selectively affect performance on composite stimuli. It is therefore not sufficient to state that this subgroup of autistic subjects might be impaired in the configural processing of unfamiliar faces. The configural information seems to be used differently in the inversion task than in the composite task. The subgroup analyses of the RTs suggest that the most important factor in this task was nonverbal ability. There was a normal composite effect in the subgroups with higher scores on the Raven, but a deviant pattern was found for autistics with the lowest nonverbal score. This is also an indication that some other factor is involved in the composite task.

5.4. General Discussion

The objective of this study was to determine whether the absence of an inversion effect in autistic subjects on tasks where photographs of faces were presented upside-down (Langdell, 1978; Hobson et al., 1988; Tantam et al., 1989) is related to a deficit in the use of the configural information of the face. The first experiment examined whether some of the these findings could be due to floor effects by administering a recognition task of inverted faces with a smaller memory component to reduce task demands. Many autistics indeed performed normally under these circumstances and showed an inversion effect for faces. Only a subgroup of autistics with a low social IQ score was still equally good in recognising inverted and upright photographs. Because the inversion effect is thought to be an effect of configural processing (Diamond & Carey, 1986; Scapinello & Yarmey, 1970; Yin, 1969), this suggests that at least a majority of the autistic subjects is able to process a face on the basis of the configuration.

In a second experiment, however, where the configural processing was tested using composite faces (Young et al., 1987), the autistic group was not better in recognising the upper half of a non-aligned composite face relative to an aligned composite face. This suggests that they were not processing faces as configurations in this task, or that besides configural processing, another factor is involved. Another indication that different processes are tapped in these tasks is Carey and Diamond's finding (1994) that the increasing vulnerability to inversion with age is independent of the composite effect.

Among the concepts used to clarify face processing, two have been widely applied: holistic and configural encoding. Holistic encoding, as used by Tanaka and Farah (1993), refers to the hypothesis that a face is represented in memory as a whole and not on the basis of its parts. Configural encoding refers to the importance of the relations among the parts for the representation of faces in memory. Carey and Diamond (1994) found that holistic encoding, which is most critical for the composite effect, is independent of age, while configural encoding, which is critical for the inversion effect, becomes more important with age. The dependence of configural encoding on age is explained by the hypothesis of norm-based coding of faces, which proposes that the facial relations may be stored as a set of norms that represents the central tendency of faces (Rhodes & McLean, 1990). As the representation of the norm gets more completely specified with experience, face encoding becomes more efficient (Ellis, 1992). The relational features are less accessible in the inverted mode, resulting in different encoding of inverted faces.

The suggestion that holistic encoding is independent of age is consistent with the finding of Kemler (1983) that young children process faces on the basis of overall similarity more than on separable stimulus structures. According to Kemler, the normal development of intelligence reflects a shift from the holistic mode to the more frequent use of the analytic mode, which is associated with differentiation. The larger composite effect in the studies by Young et al. (1987) and Carey and Diamond (1994) may be explained by a greater reliance on overall similarity in their studies than is the case in the present study. Their studies concerned a composite effect for familiar faces. They also claim that the effect holds for unfamiliar faces, but as there was extensive learning of the face halves and a requirement to name them, it is questionable whether these face halves were processed as unfamiliar faces. Furthermore, since the learned face halves were exactly identical to the face halves in the composite faces, task performance on the basis of overall similarity was very likely. The criticism concerning the unfamiliar face condition was acknowledged by Hole (1994), who tackled this problem by using a matching paradigm. The results showed that in this paradigm the composite effect also holds for unfamiliar faces. However, Hole only compared upright composites with inverted composites, but did not compare aligned composite faces with non-aligned composites. This makes a definite conclusion about the existence of a composite effect for unfamiliar faces difficult. In the present experiment, a more standard paradigm for unfamiliar face processing was used that did not require learning of the faces. The target faces were presented as a whole (instead of only showing the upper part as in the other studies) in 3/4 orientation. To reduce memory demands, the target face was immediately followed by the two composite faces in frontal orientation. This paradigm prevented recognition from occurring purely on the basis of similarity, since the top halves of the target and composite faces were not identical as was the case in the studies just mentioned. Instead, the target faces in our study had to be encoded specifically as faces and not as patterns. This encoding ability is known to be poor in children and increases with growing expertise (see Chung & Thomson, 1995, for a review). Therefore, the composite effect in our study is more affected by expertise factors than in the other studies, which may explain the smaller composite effect for children. Note that in both Experiments 1 and 2 the inspection times were prolonged for children and autistic subjects. This may have reduced developmental effects in the inversion task, but it appeared not to be sufficient to eliminate the effects of expertise in the composite task.

In contrast to children, autistic subjects did not show a composite effect. This suggests that autistic subjects might be impaired in holistic encoding of faces. A deficit in holistic encoding is also suggested by studies that used stimuli other than faces.

In the Embedded Figures task, autistic subjects were found to be superior in finding the hidden target in a camouflaging context (Shah & Frith, 1983), an indication that they show no tendency to perceive patterns as wholes. Autistic subjects also perform remarkably well on the Block Design task (Lockeyer & Rutter, 1970; Tymchuk, Simmons & Neafsey, 1977; Ohta, 1987; Bowler, 1992; Venter, Lord & Schopler, 1992). In this task subjects have to copy a given pattern with small building blocks as quickly as possible. Shah & Frith (1993) presented different variations of the Block Design task to find out what task component is responsible for the good performance of the autistic individuals. While obliqueness and rotation did not reveal group differences, it was found that autistics performed comparatively better with the unsegmented patterns. Mental segmentation of an overall shape is more difficult when the shape is perceived as a whole, which again suggests that autistic subjects do not do so. Both the findings on the Embedded Figures task and the Block Design task thus seem to suggest weak holistic encoding in autistic subjects.

Some of the most relevant studies with normal adults on holistic encoding were conducted in the seventies and concern the object and face superiority effects, the notion that array goodness or good context helps in detection of a part. In a convincing paper in which normal and scrambled faces were used as stimuli, Mermelstein, Prinzmetal, and Banks (1979) demonstrated that figures of good form lead to face superiority effects, but only when the context stimulus has to be kept in memory (the context stimulus is presented first, followed by the part to be recognised). If the part is presented first, followed by the context stimulus (and thus no memory for the context stimulus is needed), it becomes a perceptual task and then a face inferiority effect is found. Mermelstein et al. looked at face processing, but addressed the issue of context effects in such a way that the generalisation to objects is clear and they integrated the existing studies about the phenomena that have used objects (Weisstein & Harris, 1974) or faces (Homa, Haver & Schwartz, 1976).

Pursuing this line, it appears that the studies on the composite effect are perception based, as the task is a visual search of the composite faces. The results of normal subjects are consistent with the prediction made by Mermelstein et al. (1979), that, in this case, a face inferiority effect will be found. The absence of this effect in autistics would thus be due to a perceptual deficit in this group. In a memory search paradigm, Teunisse and de Gelder (submitted-c) found that the face superiority effect was smaller for autistic subjects compared to normal adults and children, although autistics too were somewhat better in recognising facial features from a coherent face than from a scrambled face. These findings are in line with the suggestion of Frith (1989) that autistic subjects exhibit a weak central coherence, an inability to integrate pieces of information into coherent wholes. The deficit seems most evident in perceptual tasks where a Gestalt-like figure has to be broken down into its constituent parts, as in a visual search task, but is also found in a memory search paradigm.

To summarise, the present findings in the composite task are consistent with an impairment in autistic subjects for holistic processing in perceptual tasks. Furthermore, the present inversion effects suggest that face encoding in most autistic adolescents is not qualitatively different from normal subjects, although they perform only at the level of 10-year-old children. Moreover, a subgroup of autistic adolescents with low social IQ scores did not show a normal inversion effect, suggesting that they do not encode faces on the basis of their second-order relational features as do normal people.

6. Face and expression superiority effects in autistic adolescents[1]

6.1. INTRODUCTION

Studies on the face processing abilities of autistic people suggest that at least three aspects of face processing are impaired. The first impairment is suggested by findings concerning the inversion effect. In one of the first studies on face processing abilities in autistic individuals, Langdell (1978) found that autistic subjects performed better than controls in recognising familiar faces in the inverted mode. Other studies also found that autistic subjects performed relatively well on inversion tasks. Hobson, Ouston & Lee (1988) found that autistics were better than controls on matching inverted photographs of faces on both identity and expression. In another study (Tantam et al., 1989), autistic subjects made more errors than controls on labelling upright facial expressions, but they were as good as the control group when the photographs were presented upside-down. In a forced-choice recognition task of unfamiliar faces, Teunisse and de Gelder (submitted-b) found that a subgroup of autistic subjects with low social IQ scores were as good on inverted faces as on upright faces. However, many autistic subjects performed like controls: they made more errors when the faces were presented in the inverted than in the upright mode, and this inversion effect was larger for faces than for shoes. The correlation between social IQ and the inversion effect suggests that in an upright face the social information is essential for normal face processing. Langdell (1978) already proposed that autistic subjects might process the face not as a "social pattern" but as a "pure pattern" (p. 266).

This is consistent with the finding that autistic subjects are also impaired in the recognition of facial expressions (e.g., Hobson, 1986 a, 1986b; Hobson, Ouston & Lee, 1988; Braverman et al., 1989). For example, Weeks & Hobson (1987) found that the saliency of facial expressions is low for autistic subjects. When autistic children were asked to sort photographs of faces on the basis of a self-chosen dimension, they preferred sorting by type of hat over sorting by expression. Even when they were explicitly asked to sort by expression, or when expression was the only discriminant feature, many autistic children had difficulties with this task. Teunisse and de Gelder (submitted-a) found evidence that the inability to recognise expressions might

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[1]Submitted for publication as: Teunisse, J.P. & de Gelder, B. Face and expression superiority effects in normals and high-functioning adolescents with autism.

The authors would like to thank Petra Piree for assistance in testing the children. We are grateful to the staff and pupils of the Dr. Leo Kannerhuis, Oosterbeek, and of Basisschool De Helle, Tilburg.

be due to a deficit in categorical perception of expressions. However, despite this deficit, many autistic subjects were able to perform normally on an expression identification task. Interestingly, a correlation with social IQ score was also found in this identification task. It was proposed that autistic subjects with more social understanding might have developed compensatory strategies for their impaired categorical perception of expressions.

Although autistic subjects seem to be impaired most seriously on the recognition of facial expressions, another aspect of face processing is affected as well. Autistic people poorly performan on unfamiliar face recognition tasks (de Gelder et al., 1991; Boucher & Lewis, 1992), which suggests a deficit in face encoding abilities (e.g., Carey, 1992).

The inversion effect, the recognition of facial expressions, and the encoding of unfamiliar faces all depend on the configural information of the face. Therefore, the pattern of results suggests that autistic subjects might process faces using a feature-based strategy and not on the basis of the configuration. This is further suggested in a study concerning the composite effect (Teunisse and de Gelder, submitted-b). In this study, a recognition task with composite faces, developed by Young, Hay, and Hellawell (1987), was adapted for studying holistic processing in autistic subjects. Normal subjects find it more difficult to recognise the upper part of a composite face when it is aligned to the bottom part, and thus a new facial Gestalt is created, than when these parts are not aligned (Young et al., 1987; Carey & Diamond, 1994). Autistic subjects did not show this composite effect.

The findings of Volkmar et al. (1989), that autistics, like controls, took more time to complete a puzzle depicting a scrambled face than an intact face, seem to contradiction these results, suggesting that they relied at least for some part on the facial configuration. However, their scrambled face was not a scrambled face in the usual sense. In most studies, a scrambled face is composed of an intact facial outline in which the spatial positions of the inner features are changed (e.g., Homa et al., 1976; Mermelstein et al., 1979; Tanaka & Farah, 1993). In the Volkmar et al. study, it was the facial outline itself that was disrupted. In that case, it is more appropriate to speak of a scrambled picture than of a scrambled face, and inferences about the processing of the facial configuration are thus hazardous.

Scrambled faces have been used as control stimuli in studies of the so-called face superiority effect (Homa et al., 1976; van Santen & Jonides, 1978; Mermelstein et al. 1979), because they consist of exactly the same features as normal faces, but only differ in their spatial organisation. The face superiority effect, a relative advantage of recognising a part in the context of a normal face compared to a scrambled face, is therefore a configuration effect. On the other hand, an intact facial configuration inhibits performance in perceptual search tasks, where a target feature has to be recognized in the context of a facial or scrambled configuration. This is known as the face inferiority effect (Mermelstein et al., 1979). The superiority and inferiority effects are not specific to facial Gestalts, but can be generalized to other meaningful stimuli that behave as Gestalts. An example of an inferiority effect is the Embedded Figures test, where a small shape is hidden in a larger complex figure. Shah and Frith (1983) found that autistic subjects were better than a control group at this task, suggesting that they were able to resist the camouflaging effect of the Gestalt pattern.

The notion of a Gestalt is used in at least two ways in the literature. Sometimes it is understood as a set of organizational principles, such as the laws of good continuation, grouping and figure-ground segregation. In the face superiority paradigms however, a Gestalt can better be understood as a familiar or meaningful stimulus derived from its configural arrangement. An intact face is a more familiar and more meaningful stimulus than a scrambled or inverted face. In this last interpretation of Gestalt, it would be interesting to see if an expression superiority effect can also be found, an advantage for normal congruent expressions over mixed or incongruent expressions. Studies of categorical perception of facial expression (Etcoff & Magee, 1992; de Gelder, Teunisse & Benson, in press; Teunisse & de Gelder, submitted-a) indicate that 'basic' expressions (Izard, 1971; Ekman, 1992), like angry, afraid, sad, happy, and disgust, are perceived categorically in normal adult subjects. This suggests that these expressions are perceived as strong Gestalts. Incongruent expressions, like chimeric faces, which consist of features with conflicting emotional cues, might not be perceived as such strong Gestalts as the basic, congruent expressions. Therefore, facial features from a congruent expression might be encoded and recognised more easily than features from an incongruent expression.

In the present study, we address three questions. In the first place, do high-ability autistic adolescents show the face superiority effect in a memory search paradigm with intact and scrambled faces? If autistic subjects have a nonconfigural processing style, no superiority effect is expected. Secondly, is there an expression superiority effect in normal adults, and is this effect absent in autistic subjects? If expressions are less meaningful to autistic subjects, one would expect that recognition of happy eyes in the context of a face with an angry mouth is as good as the recognition of happy eyes in combination with a happy mouth. Finally, the performance of autistic subjects is compared to that of 9- and 10-year-old children. If the results are similar for these groups, than this suggests that the autistic deficit is the result of a developmental lag, while a difference in response pattern between autistic subjects and children suggests that face processing is qualitatively different in autistic subjects.

6.2. EXPERIMENT: THE MEMORY SEARCH TASK

6.2.1. Method

Subjects

Seventeen autistic adolescents, 24 normal children, and 16 adults completed the task. It was assumed that subjects with a z-score below 1.65 (57% correct) responded at chance level and they were excluded from analyses. One female autistic subject and 6 children (2 male, 4 female) were excluded for this reason.

The 18 selected normal children were 9- and 10-year-old primary school pupils (10 males and 8 females). The adults (mean age 23 years; 8 males and 8 females) were undergraduate students at Tilburg University.

The 16 selected autistic subjects (13 males and 3 females), were drawn from the Leo Kanner Huis, an institute for non-retarded autistic adolescents. They satisfied the diagnostic criteria for the autistic disorder described in DSM-III-R (1987). The raw score of the Raven's matrices (Raven, 1960) was used as a measure for visuo-spatial intelligence. Verbal abilities were tested with the subtest "woordenlijst" (wordlist) of the Groninger Intelligentie Test (Luteijn & van der Ploeg, 1983). Social intelligence was tested with the Social Interpretation List (Vijftigschild, Berger & van Spaendonck, 1969) and WAIS Picture Arrangement. Social IQ score was positively correlated with the GIT wordlist ($r = .59$, $p < 0.05$). No other correlations were significant. Details of the autistic group are given in Table 6.1.

	Mean	S.D.	Range
Age	19y;8m	2y;0m	16y;4m-24y;8m
Raven raw score	40.63	8.09	25-55
GIT wordlist raw score	9.00	4.69	1-17
Social IQ score	94.38	16.52	50-115

Table 6.1. Details of the autistic subjects (N = 16; 13 males, 3 females).

Subgroups of autistic subjects were formed for analyzing the influence of age, nonverbal score, verbal score and social IQ score on performance:
Age group: 5 younger (16;4 - 18;2), 5 middle (18;7 - 20;6) and 6 older (20;7 - 24;8) subjects.
Raven group: 6 low (25 - 37), 5 middle (38 - 43) and 5 high (45 - 55) scoring subjects.
GIT group: 5 low (1 - 5), 5 middle (7 - 11) and 6 high (12 - 17) scoring subjects.
Social IQ group: 5 low (50 - 85), 5 middle (90 - 100) and 6 high (105 - 115) scoring subjects.

Materials and design

Video Floppy Disc VF-50 photographs of a male person showing 4 different emotionally 'congruent' expressions (happy, sad, angry, afraid) in frontal view were used for preparation of the stimuli. The pictures were manipulated with an image processing and production program (Aldus Photostyler). First, a standard context face was created, consisting of an outline of the face with the eyes and mouth blanked out. Then, the eyes and mouth of the 4 expressions were placed in this context face in every possible combination (e.g., happy eyes with sad mouth, sad eyes with angry mouth, sad eyes with sad mouth), yielding 16 composite faces. The same combinations of expressions were used for the scrambled face, only the position of these features was interchanged (eyes in the lower part of the face, mouth in the upper part of the face). The same context face was used, but the position of the nose was somewhat different for a better composition of the scrambled face (Appendix D).

The stimuli were presented in 2 blocked conditions: FACE (with eyes and mouth on the appropriate place) and SCRAMBLED (with eyes and mouth interchanged in location). Within the FACE condition, 4 combinations were CONGRUENT expressions (with eyes and mouth from the same expression) and 12 combinations were INCONGRUENT expressions (with eyes and mouth from different expressions). Only the 4 incongruent expressions with the same answer alternatives as the congruent expressions were used for analysis of the expression superiority effect.

A trial consisted of 2 stimuli: the context stimulus (face or scrambled) and the response stimulus (two pair of eyes or two mouths). The alternatives in the response stimulus were labelled "A" and "B". For the incongruent expressions, the alternatives were from the expressions of which the context stimulus consisted. For example, an intact or scrambled face with happy eyes and an angry mouth was followed by happy and angry eyes or happy and angry mouths. For the congruent expressions, the alternative was chosen from one of the three other expressions. Each of the 16 context combinations was presented 4 times to randomize all possible response combinations, 2 features (eyes and mouth) x 2 response alternatives ("A" and "B"), resulting in 64 trials for both the FACE and the SCRAMBLED condition. These were divided in 4 blocks of 32 trials.

Procedure

Pilot studies revealed that most of the children performed at chance level when inspection time of the first stimulus and the time-out period were too short. Therefore these were prolonged for the children. Because we learned from comparable tasks that the autistic adolescents perform at about the same level as the 10-year-old children, these changes were made for the autistics as well.

Adult subjects were tested in a sound-attenuated room. The experimenter was outside the cabin and had contact with the subject via an intercom. The distance to the monitor was 1.5 meters. Before starting the experiment, the subjects were first read the instructions of the task, and then presented a training session with 32 (16 FACE and 16 SCRAMBLED) randomized test trials.

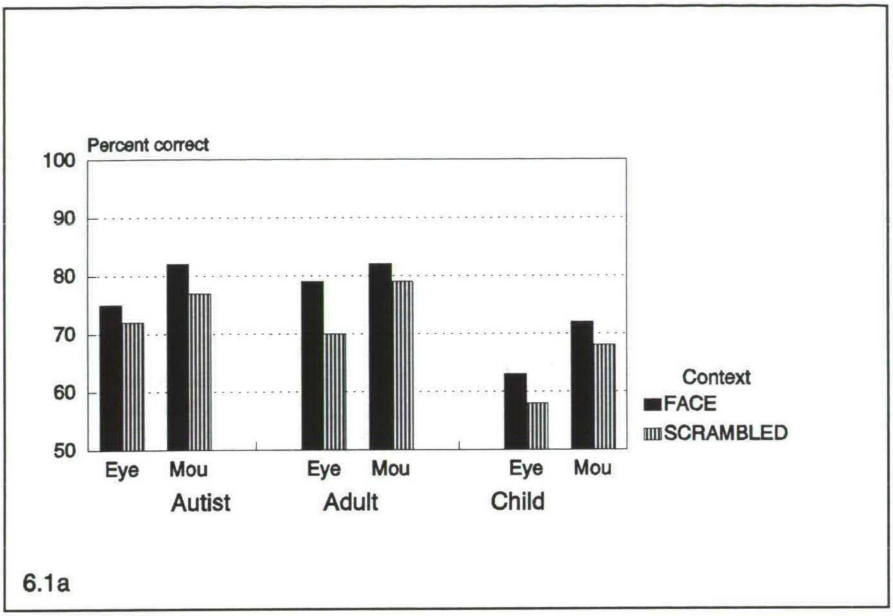
Autistic subjects and children were tested in a quiet room in the institute or school. The experimenter was in the same room as the subject during the entire experiment. Instructions were given verbally and explained with the help of photographs. Then the 32 test trails were administered.

Following the training block, 4 experimental blocks of 32 randomized trials were administered: 2 blocks of the FACE condition and 2 blocks of the SCRAMBLED condition. The order was counterbalanced within each group.

A trial was announced by an auditive warning signal, 500 msec for presentation of the first stimulus, the context stimulus. For adults, inspection time was 150 msec, for autistics and children, 1 second. 1500 msec later, 2 facial features (2 pairs of eyes or 2 mouths) labelled "A" and "B" were presented. The task was to respond as fast as possible which of the 2 features belonged to the stimulus just shown. Reactions were given by pressing one of two response buttons, also labelled "A" and "B". Reaction times were measured from onset of the response stimulus. The features disappeared when a response was given or when the time out period was exceeded (1 second for adults and 3 seconds for autistics and children). The intertrial interval was 3 seconds.

6.2.2. Results

Results were analyzed for correct responses and for RT of correct responses. Context effects are presented in Figure 6.1 and expression effects in Figure 6.2.



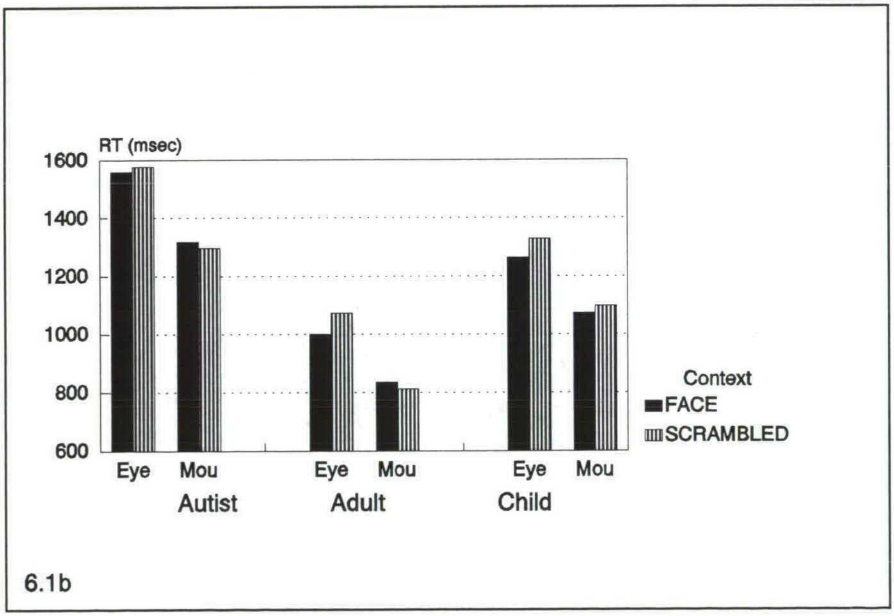
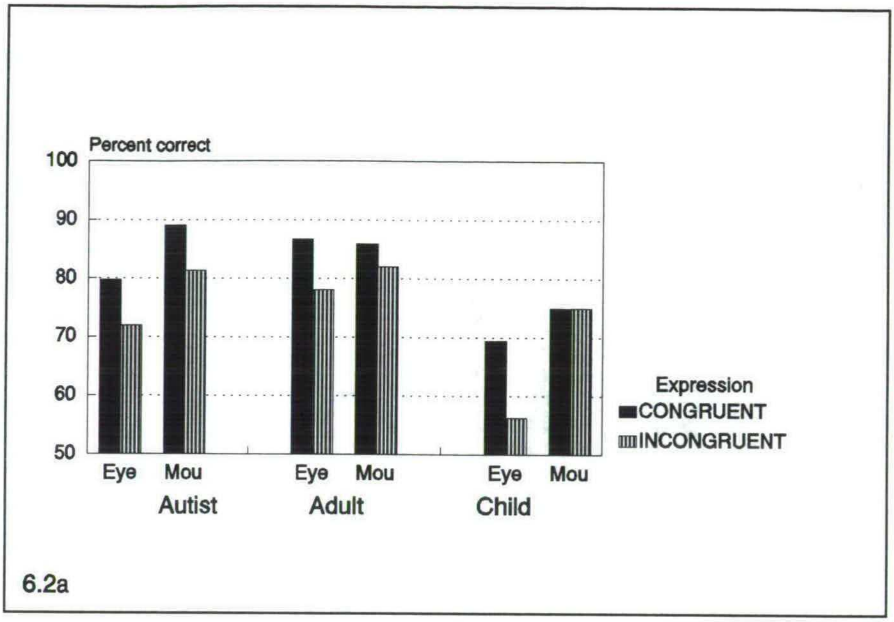


Figure 6.1. Results of the face and scrambled conditions on eyes and mouth features.
a. Mean percentage correct for the three groups.
b. Mean RT for the three groups.



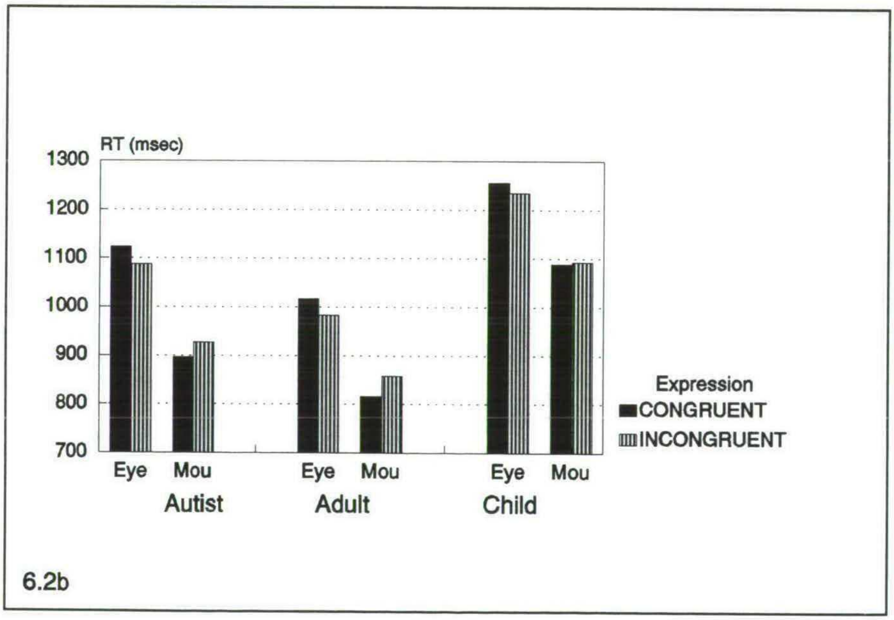


Figure 6.2. Results of the congruent and incongruent expressions for the eyes and mouth features.
a. Mean percentage correct for the three groups.
b. Mean RT for the three groups.

The results of the children and adults are described first. A separate analysis for each group was carried out with a repeated-measures ANOVA using Context (FACE versus SCRAMBLED) and Feature (EYES versus MOUTH) as within-subject factors. Within the FACE condition, a repeated measures ANOVA was carried out with Expression (CONGRUENT versus INCONGRUENT) and Feature (EYES versus MOUTH) as within-subject factors. For this analysis, the congruent expressions were compared with the incongruent expressions that contained the same alternatives. Differences in accuracy and RT between CONGRUENT and INCONGRUENT could, therefore, only be attributed to the context feature. Group comparisons were made with a repeated-measures ANOVA using the same within-subject factors, and Group (adult versus child) as a between-subject factor.

Then the results of the autistic group are described. First the autistic subjects were analyzed as a group, then they were compared to both the adults and the children, with the same statistical tests as before. Finally, autistic subgroup results were analyzed with a repeated-measures ANOVA using Subgroup (low, middle, high) as a between-subject factor and the same within-subject factors as before.

Adults versus children

Both groups were more accurate on normal faces than on scrambled faces, although this was significant for adults ($F(1, 15) = 10.11$, $p = 0.006$) and only a trend for children ($F(1, 17) = 3.31$, $p = 0.087$). For adults, this effect of context was larger for eyes than for mouths (interaction Context x Feature: $F(1, 15) = 4.84$, $p = 0.044$). In the RT analysis, a normal face context was only facilitating for adults on eyes and not on mouths (interaction Context x Feature: $F(1, 15) = 9.27$, $p = 0.008$). Children were also slower in the scrambled context relative to the face context ($F(1, 17) = 6.16$, $p = 0.024$), and although this effect was somewhat larger for eyes than for mouths (see Figure 6.1b), the Context x Feature interaction was not significant for them ($F(1, 17) < 1$).

For both groups, mouths were easier than eyes, reflected in higher accuracy (adults: $F(1, 15) = 5.90$, $p = 0.028$; children: ($F(1, 17) = 10.42$, $p = 0.005$) and much shorter RTs (adults: ($F(1, 15) = 110.02$, $p < 0.001$; children: $F(1, 17) = 116.79$, $p < 0.001$). Children made more errors ($F(1, 32) = 31.90$, $p < 0.001$) and were slower ($F(1, 32) = 61.00$, $p < 0.001$) than adults.

Figure 6.2a shows that responses on congruent expressions tended to be more accurate than on incongruent expressions. In the overall analysis of adults and children this was a significant effect ($F(1, 32) = 6.19$, $p = 0.018$), but in the separate analyses it was a trend for adults ($F(1, 15) = 4.14$, $p = 0.060$) and not significant for children ($F(1, 17) = 2.69$, $p > 0.1$). However, an expression superiority effect was found for children as a trend for eyes and not for mouths (interaction Expression x Feature: $F(1, 17) = 3.19$, $p =$

0.092). The RT pattern seems to indicate that responses on eyes are slower and responses on mouths are faster in congruent expressions (Figure 6.2b), but this is only reflected in a trend for adults (interaction Expression x Feature: $F(1, 15) = 4.11$, $p = 0.061$).

Autistics versus adults and children

Figure 6.1a shows that autistic subjects, like adults and children, were more accurate on normal faces than on scrambled faces, although this was reflected in the analyses only as a trend ($F(1, 15) = 3.20$, $p = 0.094$). The significant Group x Context x Feature interaction in the group analysis with adults ($F(1, 30) = 4.23$, $p = 0.049$) showed that, unlike adults, the context effect was not larger for eyes than for mouths in autistic subjects. The RT pattern was similar to that of the control groups (no Group interactions, see Figure 6.1b), but differences on context stimuli were not significant in the autistic group ($F(1, 15) < 1$).

Autistic subjects were as accurate as adults ($F(1, 30) < 1$), but slower ($F(1,30) = 32.11$, $p < 0.001$). They were also slower than children ($F(1, 32) = 8.46$, $p = 0.007$), but made fewer errors ($F(1, 32) = 13.60$, $p = 0.001$). Autistic subjects were somewhat better ($F(1, 15) = 3.87$, $p = 0.068$) and much faster ($F(1, 15) = 46.74$, $p < 0.001$) on mouths than on eyes.

Figure 6.2 shows that the response and RT patterns of autistic subjects is similar to the control groups. The higher accuracy on congruent expressions relative to incongruent expressions was a trend ($F(1, 15) = 3.57$, $p = 0.078$), but the RT interaction Expression x Feature was not significant ($F(1, 15) = 1.97$, $p > 0.1$).

Autistic subgroups

Scores on the task significantly correlated with scores on the Raven ($r = .58$, $p < 0.05$). Significant correlations of Raven with eyes (FACE-EYE: $r = .53$, $p < 0.05$; SCRAMBLED-EYE: $r = 0.72$, $p < 0.01$) and not with mouths, suggest that nonverbal ability was important for feature analysis of the eyes, which were the more difficult feature (more errors and slower RT). Although correlations with age were not significant, the oldest Age group was more accurate on this task than the younger groups ($F(2, 13) = 8.92$, $p = 0.004$). There were no RT effects.

No interactions in accuracy or RT were found between any subgroup and type of expression (congruent versus incongruent).

6.3. DISCUSSION

In the present experiment, the face superiority effect in high-ability autistic adolescents was studied in a memory search paradigm with intact and scrambled faces. Furthermore, it was examined whether an expression superiority effect could be found, the effect that facial features are better recognized in the context of a congruent expression than in an incongruent expression. The performance of the autistic subjects was compared to that of normal adults and children.

Group comparisons revealed that there were only minor differences in response pattern between the three groups. Accuracy was better on intact faces than on scrambled faces for all three groups, although this was significant for adults and only a trend for autistic subjects and children. Eyes were recognized faster in the context of intact faces than scrambled faces, but this was not significant for autistic subjects. Although the expression superiority effect was only weak, there was a trend that features were better recognized in congruent expressions than in incongruent expressions in the three groups.

These results show that the response pattern was similar for the three groups, although the superiority effects were smaller for children and autistic subjects than for adults. One possible explanation for this difference is the longer inspection time for the context stimuli in children and autistic subjects compared to adults. For adults, the short inspection time (150 msec) did not allow for post-perceptual processing of the stimuli. The near-threshold presentations of the context stimuli forced the adult subjects to encode the stimuli purely on the basis of the figural whole. This is easier when the stimulus figure is a good Gestalt, such as a normal face, than when it is not, as in case of a scrambled face. Pilot studies showed that children and autistic subjects performed at chance when the context stimuli were shown for only 150 msec. Therefore, the exposure times were prolonged to 1 second. However, the prolonged exposure times may have enabled them to encode the individual facial features post-perceptually in a piecemeal way. Such a processing strategy is, by definition, less sensitive to context, which may result in a smaller face superiority effect.

Carey and Diamond (1994) argue that the encoding difficulties in children are due to an inability to process faces configurally. They distinguish two encoding processes that are important for the recognition of faces. The first is holistic encoding, the encoding of a face as a whole without explicit representations of the individual facial features (Tanaka & Farah, 1993). The second process is configural encoding, which is encoding a face on the basis of its second-order relational features (Diamond & Carey, 1986). Carey and Diamond (1994) propose that both processes influence performance on the Composite task (Young et al., 1987). In this task, two face halves from different individuals are aligned to form a new facial Gestalt. The recognition of the upper half of this composite face requires a perceptual analysis of the facial Gestalt, which is more difficult for aligned compared to nonaligned composites. According to Carey and Diamond (1994), this is because subjects have to resist the tendency to perceive the stimulus holistically, thus with no explicit representation of the constituent parts. This effect is independent of age, suggesting that both adults and children perceive a face holistically. However, adults and children were different in processing the configural aspects of a face. This was concluded on the basis of the performances on inverted photographs of composite faces. Recognition is more difficult when a face is presented upside-down compared to a normal upright presentation, because it is thought that it is not possible to process the second-order relational features to the same extent in inverted faces (Diamond & Carey, 1986). Carey and Diamond (1994) found that when the composite faces were presented upside-down, recognition performance of the upper half was disrupted more in adults than in children. Other studies have shown that this developmental effect of inversion is also found with intact faces (e.g., Carey, 1983; Flin, 1983). On the basis of these findings, Carey and Diamond argue that children do not yet have the capacity to use the configural information of a face efficiently in face encoding. This also limits their performance in unfamiliar face recognition tasks (see Chung and Thomson, 1995, for an overview of face perception abilities in children).

The present face superiority task did not require a visual search of a context stimulus, since the facial features were presented in isolation. However, the results show that a memory search for a feature is more efficient when the feature has previously been encoded in the context of a facial configuration than in a scrambled configuration. This seems to suggest that configural encoding has a beneficial effect on the representation of the individual features of a face. The features seem to be represented in relation to each other, and this allows a better recognition when they are later presented in isolation.

Since the studies on inversion effects and unfamiliar face recognition suggest that children are less able than adults to encode faces on the basis of their second-order relational features, the facial features will probably also be encoded less efficiently in memory, yielding a smaller face superiority effect. The fact that there is also a trend for an expression superiority effect, is consistent with the proposal that the second-order relational features are essential to finding superiority effects in a memory search paradigm.

The weaker face superiority effect in autistic subjects suggests that they also are less efficient in encoding the relational features of a face. This is in line with other evidence. In a forced-choice recognition task with inverted photographs of faces, autistic subjects had a performance pattern that was very similar to that of children (Teunisse & de Gelder, submitted-b). Furthermore, like children, they performaned poorly in recognition tasks of unfamiliar faces (de Gelder et al., 1991; Boucher & Lewis, 1992).

However, autistic subjects are different from children on tasks in which subjects are required to do a perceptual analysis of a Gestalt pattern. Unlike children, autistic subjects do not exhibit the composite effect (Teunisse & de Gelder, submitted-b). Also the findings that autistic subjects perform relatively well on the Embedded Figures task (Shah & Frith, 1983) and on a segmenting condition of the Block Design test (Shah & Frith, 1993) are consistent with this suggestion. Apparently, autistic subjects do not automatically perceive the Gestalt properties of a stimulus. This suggest that they have a deficit in the pre-attentive processes that are believed to be responsible for perceiving meaningful and familiar stimulus patterns as Gestalts (Pomerantz, 1981). In the pre-attentive processing stage, a stimulus is perceived and recognised on the basis of both data-driven (bottom-up) and concept-driven (top-down) processes. The fast and automatic recognition of meaningful and familiar stimuli, such as faces and expressions, is based on the concept-driven analyses of the incoming information. In autistic subjects, this concept-driven perception seems to be impaired.

In terms of the face superiority and inferiority effects as described by Mermelstein et al. (1979), this means that autistic subjects exhibit a weak face superiority effect in a memory search paradigm, and no face inferiority effect in a visual search paradigm. Autistic adolescents are similar to children in their poor face encoding abilities. Because they are less able to use the configural aspects of a face in face encoding, they are forced to use post-perceptual strategies that are based on piecemeal processing in a memory search task. Autistic adolescents are different from children in the perception of Gestalts. Whereas children automatically recognise meaningful and/or familiar stimuli by concept-driven processes, autistic subjects are impaired in these processes.

This interpretation seems a further specification of the theory of weak central coherence in autistics, as was proposed by Frith (1989). According to this theory, autistic subjects are disturbed in the integration of fragmentary information into meaningful and coherent wholes. The experiments concerning the face superiority and inferiority effects suggest that the deficit is primarily a perceptual impairment, although encoding processes are affected as well.

7. Summary and conclusions

7.1. INTRODUCTION

The present thesis was concerned with face perception in autistic individuals. As the literature overview in the introductory chapter showed, the findings of previous studies were rather complex and not always consistent. Whereas some studies have found a selective impairment in the recognition of facial expressions, other studies have found a more general deficit in perceptual abilities, and some have failed to find any differences between autistic subjects and controls. Moreover, impairments beyond expression recognition, for example, the recognition of unfamiliar faces, appeared to be affected in autistic subjects. Furthermore, autistic subjects seemed to pay relatively more attention to the lower part of the face, they were found to make more use of verbal strategies in expression recognition, and a remarkably high level of performance was found on tasks with inverted photographs of faces. Previously, no serious attempt was made to place these different findings in a comprehensive theoretical context. One of the aims of this thesis was to contribute towards providing such a context. To this end, experiments and models of normal face processing were reviewed and discussed in the introductory chapter. This included the description of a functional architecture of face perception, a prototype model of mental representation, studies concerning the recognition of facial expressions, and the development of face perception skills.

The introduction concluded with the research strategies for the present thesis. Because the majority of previous studies were concerned with examining whether a function is or is not impaired in autistic subjects, we argued that a different approach would be more informative for the study of face perception. Instead of concentrating on the selectivity of the impairments, the research questions focussed on the underlying processes of these impairments by using paradigms from cognitive (neuro)psychology. The three main questions addressed in this thesis were:

1. *Are the impairments in face processing due to one underlying deficit, or are separate modules affected in autism?*
2. *Are facial expressions perceived categorically, and is this ability impaired in autism?*
3. *Are autistic individuals impaired in the configural and holistic processing of faces?*

7.2. OVERVIEW OF THE PRECEDING CHAPTERS

To examine the first research question, a clinical task battery of face perception (Bruyer & Schweich, 1991) was administered that systematically tapped the processing modules which were proposed in the functional model developed by Bruce and Young (1986). Because findings from the literature suggest that autistic subjects are selectively impaired in the recognition of facial expressions and unfamiliar faces, it was expected that they would perform poorly on tasks that tapped these abilities. However, these hypotheses were not confirmed by the results. Although this suggests that autistic subjects have at least a minimal ability to process unfamiliar faces across different expressions and poses and to categorise photographs on facial expression, the question was also raised whether this task battery, originally designed to investigate face processing in prosopagnosia patients, is sensitive enough to detect possible impairments in autistic subjects. For example, the task concerning unfamiliar face processing involved matching a target face to one of nine distracter faces that differed in expression or pose. Such a task allows matching on salient perceptual cues, instead of matching on facial identity. A more sensitive test should require the subject to encode the face in a face-specific manner to ensure that the test was really about unfamiliar face processing. The same objections given for the unfamiliar face matching task can be made about the expression-matching task. In this task, only three different expressions (happy, sad, and a face pronouncing "O") had to be categorised. The expressions were very dissimilar, and an example photograph was used for every label. In this task, as in the previous one, performance could be based purely on perceptual matching, rather than expression-specific processing. Therefore, possible deficits are not easily detected by this test.

However, there were two tests on which both the youngest children (7-10 years old) and the autistics made more errors than older children and adults. One was the recognition task of famous faces. The poor recognition scores in the two groups could be due to their not being familiar with the famous faces rather than a different processing style. This was also suggested by the significant correlation with age. Furthermore, there are no indications in the literature that children or autistics are impaired in recognising familiar faces.

More interesting was the other test in which the two groups encountered difficulties, a matching task of facial features which were placed in the context of a complete face. The target face and the four distracter faces were all identical except for the relevant feature (eyes, nose, or mouth). Other tests in the task battery, in which the context was reduced or absent, showed that both groups were able to discriminate between the features. This suggests that autistic subjects and young children may not be able to analyze a face efficiently for relevant cues. They seem to use a global scanning strategy that is not suitable to this task. Kemler (1983) suggested, on the basis of face categorisation tasks, that young children use a holistic style of processing that is based on overall similarity of faces. Only later do they learn to use analytical strategies, which enable them to differentiate between faces. In the Complete Context task, all faces look very similar, and an analytic processing mode is needed to detect and discriminate the relevant feature. However, it should be noted that Kemler (1983) used the concept of holistic processing differently than Tanaka and Farah (1993), who defined it as the representation of a face as a whole with no explicit representations of the constituent parts. In this thesis, Tanaka and Farah's definition of holistic processing is adapted. The processes described by Kemler (1983) concern categorising on the basis of overall similarity and may be termed global processing. In the complete-context feature-matching task, autistics and children seem to use a global scanning strategy where an analytical strategy would be more efficient.

In conclusion, the clinical task battery did not appear to be sensitive enough to reveal some of the selective impairments that were predicted, but it showed that autistic subjects were similar to 7- to 10-year-old children in the complete-context feature-matching task, a task that is supposed to concern the structural encoding module in the Bruce and Young model (1986). An important implication of this finding is that the deficit is in the early processing stage of structural encoding, which precedes all other face processing stages. According to the Bruce and Young model (1986), this would mean that all aspects of face perception should be affected. This is not in line with the empirical findings in both autistic subjects and young children, who are, for example, not impaired in familiar face recognition. Apparently, the functional model is not suited for tackling the questions of the development of face processing nor for investigating detailed deficits in autistics.

The next research question focused on the face processing capacity that is thought to be most impaired in autistic: the recognition of facial expressions. As the expression task of the task battery made clear, not every task is appropriate for revealing possible deficits. Furthermore, when it is found that performance on a certain task is poor, it is not always clear which processing component is impaired. For example, an impairment in the recognition of expressions may be due to a deficit in the ability to process configural information or to a disturbance at a conceptual level. In this thesis, this issue was examined by studying the categorical perception of expression in autistic adolescents and normal adults and children.

Etcoff and Magee (1992) adapted a paradigm used in categorical perception studies of speech to study the categorical perception of expressions. They constructed several expression continua of line drawings from one prototypical expression to another. With these stimuli, they conducted two tasks: an identification task and a discrimination task. In the identification task, the subjects chose which of two expressions was depicted in a drawing. On the basis of these results, the category boundary between two expressions could be estimated. In the discrimination task, face-pairs that differed in equal steps on a continuum had to be discriminated. They found that for most continua, between-category face-pairs were discriminated more accurately than within-category pairs. They considered this to be evidence of categorical perception of these expressions.

This paradigm was further explored in the present thesis. However, a number of significant additions were made. First, photo-realistic stimuli, which were created using a morphing technique, were used instead of drawings. In addition to accuracy scores, reaction times were also analyzed. Furthermore, a condition was added in which the stimuli were presented upside-down, to control for possible dichotomisation artefacts. To investigate developmental factors of categorical perception, the tasks were administered to both adults and children. Finally, a goodness-rating task was added in order to study the internal structure of the categories.

The main results were that the findings of categorical perception were replicated in normal adults and children. The results of the task with inverted presentation indicated that the findings could not be due to dichotomisation artefacts. Within-category performance was above chance, and the goodness ratings and RT results also showed that subjects perceived prototypical expressions as the best exemplars of a category. Apparently, subjects can acknowledge that certain expressions belong to the same category while still being able to discriminate subtle differences between them.

In the subsequent study, the same paradigm was used to explore whether the impaired expression recognition in autistic subjects can be due to a deficit in categorical perception. The results on the discrimination task suggest that this is the case. Autistic adolescents were not more accurate on discriminating between-category pairs than within-category pairs. Interestingly, many autistic subjects exhibited a normal response pattern in the identification task. Only the autistic subjects with low social intelligence were unable to recognise the prototypical expressions. The finding that the other autistic subjects were not impaired in this task, even though their recognition was not based on categorical perception, suggests that they used compensatory strategies, possibly based on a more analytical processing style. This may be one reason for the contradictory results in expression recognition studies with autistic subjects.

A question not answered by the present studies is whether categorical perception is based on a biologically endowed mechanism that is tuned to the configurations corresponding to the basic emotions, or whether categories are developed as a result of experience. A recent study by Beale and Keil (1995) concerning the categorical perception of familiar faces is of interest here. They found that familiar faces, which only become familiar through experience, were also perceived as distinct categories with clear category boundaries. If categorical perception of expressions also results from learning, then the next question should be why autistic subjects do not acquire this perceptual ability.

One possibility is that autistic subjects are impaired in the ability to process relational features, the configuration that defines an expression. There are two findings that are consistent with this hypothesis. First, autistics perform poorly on unfamiliar face recognition tasks (de Gelder et al., 1991;

Boucher & Lewis, 1992). Studies on normal face perception indicate that unfamiliar faces are encoded on the basis of their second-order relational features, the distinctive relations among the elements of a facial configuration (e.g., Diamond & Carey, 1986). The processing of these configural aspects of a face is disrupted when a face is presented upside-down, a phenomenon known as the inversion effect. Several studies suggest that autistic subjects are less disrupted by inversion (Langdell, 1978; Hobson et al., 1988; Tantam et al., 1989), which indicates that they normally process faces less on the basis of the configuration than other people do. These two findings, impaired recognition of unfamiliar faces and good performance on inverted photographs of faces, thus indicate that configural processing might be impaired in autistic subjects.

The first experiment which examined this hypothesis was an adapted version of the inversion task. The previous studies on inverted photographs of faces with autistic subjects used different paradigms and defined the inversion effect differently. Furthermore, some of the findings could be attributed to floor effects. Therefore, a task was constructed with relatively easy task demands. Instead of first presenting a set of photographs to be kept in memory, every trial started with the short presentation of one face in frontal view, followed by a two-alternative forced-choice recognition task two seconds later. The photographs of the faces in the recognition test had a different perspective (3/4 view) than the target photograph (frontal view). This was done to encourage face-specific encoding processes in the subjects. Accuracy and reaction time data on inverted presentation were compared to performance on upright presentation of the photographs.

The results revealed that most autistic adolescents exhibited the normal inversion effect: upright faces were recognised faster and more accurately than inverted faces. Furthermore, this effect was greater for face stimuli than for object stimuli (shoes), a finding that is consistent with studies in normals. Only autistic subjects with low social IQ scores did not show the inversion effect. They were not different from the other autistics in performance on the inverted photographs but did not, like the others, perform better in recognizing upright faces. However, it must be noted that the presence of an inversion effect in the autistic group does not automatically imply that the encoding of faces is normal. They made more errors and were slower than normal adults, even though the inspection time of the target photographs was prolonged. Their response pattern was very similar to that of the children, who are known to have smaller inversion effects. The adapted paradigm controlled for floor effects, but thereby may also have obscured developmental effects. The results do suggest that the encoding of faces is qualitatively the same for adults, children, and autistics, with children and autistics not being as efficient as adults. They seem to use the configural information of a face for face encoding, but less effectively.

The correlation of the inversion effect with social intelligence in the autistic group is interesting, among other things, because social intelligence was found, in the categorical perception study, to be correlated with the ability to recognise facial expressions in the identification task. It is not clear whether this correlation indicates that autistic subjects with higher social IQ scores learn that the configural information is important for the encoding of a face or whether autistic subjects with a more configural style of face processing are more sensitive to social information and, therefore, have more potential to develop their social skills. Longitudinal studies of autistic individuals tested on social IQ and configural processing may clarify this issue in the future.

The impairments in expression recognition and unfamiliar face recognition may also result from impaired holistic processing of faces. While configural processing concerns encoding faces on the basis of the second-order relational features (e.g., Carey & Diamond, 1994) which develop with experience, holistic processing is the encoding of faces as a whole, with no explicit representations of the constituent parts (e.g., Tanaka & Farah, 1993). Autistics perform extremely well on perceptual tasks where a Gestalt pattern has to be segmented into its constituent parts, as in the Embedded Figures task (Shah & Frith, 1983) and the Block Design task (Shah & Frith, 1993). According to Frith (1989), the reason is that autistic subjects have weak central coherence, an inability to integrate fragmentary information into coherent and meaningful wholes. This deficit might also impair holistic encoding of faces as this involves perceiving a face as a meaningful whole.

Young, Hellawell, and Hay (1987) constructed a task in which the upper half of composite faces had to be recognised. They found that this was more difficult when the face halves were aligned, and thus formed a new facial Gestalt, than when they were not aligned. The effect was the most convincing when the faces were familiar. They claimed that the effect was also found for unfamiliar faces, but as subjects were trained on these faces, it is doubtful whether the processing was still that of unfamiliar faces. Carey and Diamond (1994) replicated the composite effect with children and found no interaction with age. They suggested that these findings were related to holistic processes, in contrast to the inversion effects, which were attributed to configural encoding processes. Thus, if autistic subjects are impaired in holistic processing, they are expected to show no composite effect.

This prediction was tested in an adapted version of the composite task. The stimuli were unfamiliar faces, and the task was constructed in such a way that no learning of the faces was required. As in the inversion task, every trial started with presentation of the target face, immediately followed by two composite faces. The subject had to recognise the upper half of these composites. The orientation of the target face (3/4 view) and composite faces (frontal view) were different to encourage face-specific encoding. It appeared that also in this modified paradigm, composite effects were found in the normal subjects, although the effects were somewhat smaller. In contrast to the Carey and Diamond (1994) study, the effect was smaller for children than for adults. This is not consistent with the claim that holistic processing is independent of age. However, in the present experiment, task requirements were far more face-specific, and face encoding abilities are known to develop with age.

Although the autistic data were very similar to that of the children, there was not a significant composite effect in this group. This confirmed the hypothesis that autistic subjects are impaired in holistic processing of faces. The existing evidence suggests that this deficit is most evident in perceptual tasks where a Gestalt figure has to be analyzed for its parts. It is less clear whether this deficit also impairs performance on tasks that require memorising a perceptual Gestalt.

To study this suggestion, a task was constructed that was inspired by the face superiority experiments done in the 1970s (Homa, Haver & Schwartz, 1976; van Santen & Jonides, 1978; Mermelstein, Prinzmetal & Banks, 1979). In the typical face superiority task, a context stimulus (an intact face or a scrambled face) is presented briefly, followed by a forced-choice recognition task for facial features (eyes, nose, or mouth). It was found that features are recognised better when they are memorised in the context of a normal face as opposed to a scrambled face. Mermelstein et al. (1979) showed that the memory component is crucial for finding a face superiority effect. When the task requires a perceptual search of the context stimulus, the opposite effect will be found, a face inferiority effect. In that case, the facial Gestalt inhibits the visual search for a constituent part. They claim that this is not specific to face perception but is true of all tasks in which a meaningful context is present, such as tasks concerning the word superiority effect (Reicher, 1969) and the object superiority effect (Weisstein and Harris, 1974). The results in the Embedded Figures task and the composite task can also be understood as Gestalt inferiority effects.

The last experimental study used a version of the standard memory search paradigm with intact and scrambled faces (Mermelstein et al., 1979) to examine face superiority effects in children, adults, and autistic adolescents. The stimuli were chimeric male faces, in which the facial features from four different expressions were combined, both in a facial configuration and in a scrambled configuration. This not only allowed the study of the face superiority effect by comparing performance on normal faces with scrambled faces, but also the possible existence of an expression superiority effect, by comparing the configuration of a congruent expression (e.g., happy eyes with a happy mouth) with that of an incongruent expression (e.g., happy eyes with a sad mouth). The results showed that the three groups performed better in the face condition than in the scrambled condition, although this face superiority effect was smaller for autistic subjects and children than for adults. Furthermore, facial features were recognised somewhat better when they were encoded in a face with a congruent expression than in one with an incongruent expression, which is the first empirical evidence for an expression superiority effect.

The fact that the superiority effects were smaller for children and autistic subjects might have been due to the longer exposure times of the context stimuli (1 sec) for these groups. The longer exposure times were necessary because a pilot study revealed that these subjects performed at chance level, when the stimuli were presented for a shorter time (150 msec). However, the longer presentations might have allowed the children and autistics to use post-perceptual piecemeal encoding strategies which are by definition less sensitive to context effects.

The poor performance of children and autistic subjects in the pilot study may be related to their inefficiency in processing the configural aspects of a face, which was already suggested by the smaller inversion effects and the poor performance on unfamiliar face recognition tasks in these groups. Configural encoding, which is thought to be face-specific (Carey & Diamond, 1994), may, to a great extent, contribute to the face superiority effect. When a face is encoded configurally, the individual features are encoded interrelatedly, which may facilitate later recognition of the isolated features. The less efficient configural encoding ability of autistics and children would thus yield smaller face superiority effects. Developmental findings suggest that this ability improves with age in normal children, whereas the present results seem to indicate that autistic subjects do not develop their configural processing ability significantly.

In summary, the findings on unfamiliar face recognition tasks, inversion tasks, and face superiority tasks suggest that autistic adolescents are very similar to 10-year-old children in the encoding of faces in memory. This seems to argue for a developmental lag in face encoding in autistic subjects. However, autistic individuals seem to process faces qualitatively differently from normal children (and adults) in tasks in which a perceptual analysis of a Gestalt pattern is required. Whereas normal children automatically perceive and recognise a meaningful and/or familiar stimulus, such as a face, due to concept-driven processes in the pre-attentive stage (e.g., Pomerantz, 1981), autistic subjects are impaired in these processes. This last suggestion predicts that autistic subjects will exhibit no face inferiority effect in a perceptual search task, a prediction that now awaits empirical support from future research.

7.3. CONCLUSIONS

The findings in the present thesis suggest that, in some aspects of face processing, autistic adolescents are very similar to 10-year-old children, suggesting a developmental delay. Like children, autistic adolescents use global scanning strategies that are based on overall similarity. Furthermore, autistic subjects and normal children are less able than adults to use the second-order relational features of a face for encoding a face in memory. On the other hand, autistics differ from children in their perception of Gestalt patterns. Perception in autistics seems less concept-driven, they are less inclined to automatically attach meaning to a stimulus. This deficit may also be responsible for the absence of categorical perception of facial expressions in autistics. Autistics perceive a facial expression as a neutral stimulus that is not automatically classified in an emotional category. To cope with this deficit, some autistic individuals learn to use compensatory strategies for recognising facial expressions, but these are not based on categorical perception.

The present studies on face perception were not conducted primarily to test the validity of theories of autism (see section 1.1.2.), but it would be interesting to see how the findings relate to some of the ideas that have been recently advanced to understand autism. The interpretations of the present findings are based on information processing theories, and this may suggest that a socio-affective explanation of the autistic syndrome could be discarded. However, the affective-cognitive dichotomy is probably not a useful one, since affective impairments can be described in cognitive terms. The impaired categorical perception of facial expressions, for example, can be considered an affective disorder, but a cognitive approach is useful for understanding the underlying mechanisms.

However, the information processing approach fits more easily into theories that are also described in these terms. The findings concerning the impaired holistic processing in a visual search task seem to support Frith's theory (1989) of weak central coherence in autism since these findings suggest that a Gestalt pattern is not perceived as a coherent whole. The present thesis contributes to a further specification of the theory in that it states that the deficit is primarily perceptual. Meaningful and familiar stimuli are not perceived as Gestalts because top-down processes that use long-term memory representations for automatic perception and recognition are impaired. The fundamental proposal is that the mental representations in autistic subjects may be relatively intact, but the use of these representations for perception, and perhaps other internal processes, is impaired. This deficit may also explain why autistic subjects pay attention to other parts of the face than normals (Langdell, 1978). Their scanning of the face seems to be less guided by meaning and, therefore, they do not pay more attention to parts of the face that contain important social information, such as the eye region.

The present interpretation probably fits best in the executive function approach (Ozonoff, Pennington & Rogers, 1991), which assumes that organised search and working memory is impaired in autistic individuals. Such a deficit would not only impair perception and attention processes, but also mental operations that require active use of incoming information. Hammes and Langdell, (1981) for example, found that autistic children attained normal object permanence, but they were unable to use it to predict and anticipate states of objects. Shulman et al. (1995) found that autistic subjects were selectively impaired on tasks that require internal manipulation of information, a process they called 'operativity'. It is possible that the impairment in using information for understanding, predicting, and anticipating events also plays a role in 'theory of mind' tasks (e.g., Baron-Cohen, Leslie & Frith, 1985). The performance of autistic subjects on these tasks would then not be the result of the absence of a 'theory of mind', but of an inability to use this information. It would also account for the finding that some autistic subjects may improve in social IQ score as a result of training without improving to the same extent in social competence (Schatz & Hamdan-Allan, 1995). Apparently, they cannot apply the knowledge they have about social interaction in daily-life situations.

In conclusion, autism is a complex syndrome that should be studied across various disciplines to search for supplementary support for a comprehensive theory in the future. An information processing approach that not only examines *which* functions are impaired, but also *how* they are impaired, is a valuable contribution to the understanding of autism. The study of face processing must be viewed as an opportunity to investigate some of the most marked impairments of the syndrome. By putting the results both in the context of normal face processing theories and recent theories of autism, a picture of autism emerges that indicates which impairments are quantitative, resulting from a developmental lag, and what distinguishes autism qualitatively from normal development.

8. References

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Samenvatting

Dit proefschrift handelt over gezichtswaarnemingsprocessen bij autisten. Het doel is om via onderzoeksmethoden uit de cognitieve (neuro)psychologie tot een beter begrip van deze processen te komen. Ter inleiding wordt in Hoofdstuk 1 eerst enige achtergrondinformatie verstrekt. Hierbij komen de ontwikkeling van diagnostische criteria en enkele recente theorieën over autisme ter sprake. Vervolgens wordt een chronologisch overzicht gegeven van studies naar de gezichtswaarneming bij autisten. Deze onderzoeken worden geplaatst in de context van de normale ontwikkeling van de gezichtswaarneming. Daarbij komen modellen aan bod die de informatieverwerking en mentale representatie van gezichten beschrijven, onderzoeken betreffende de herkenning van gezichtsexpressies, en de ontwikkeling van gezichtswaarnemingsprocessen bij kinderen. Het inleidend hoofdstuk sluit af met de onderzoeksstrategieën van dit proefschrift.

Hoofdstuk 2 beschrijft het eerste experimentele onderzoek: een klinische taakbatterij voor gezichtswaarneming (Bruyer & Schweich, 1991). Deze batterij was oorspronkelijk ontworpen voor het bestuderen van prosopagnosie, en is gebaseerd op het gezichtswaarnemingsmodel van Bruce en Young (1986), waarin de verschillende aspecten van gezichtswaarneming worden beschreven als onafhankelijke modules. De batterij bestaat uit een serie taken die elk zo'n verwerkingsmodule onderzoekt. De resultaten laten zien dat autisten en kinderen moeite hadden met het matchen van gezichtsonderdelen (ogen, neus of mond) als deze werden aangeboden in de context van een compleet gezicht. Wanneer de gezichtscontext ontbrak of slechts beperkt was (alleen de gezichtsomtrek), verschilden zij niet met volwassen proefpersonen. Autisten en jonge kinderen waren dus in staat de verschillen tussen de onderdelen waar te nemen, maar wanneer deze waren geplaatst in een complexe context hadden zij moeite het gezicht te analyseren voor het relevante onderdeel. Zij leken een globale scanningsstrategie te gebruiken, die is gebaseerd op de algemene gelijkenis tussen gezichten, waar een analytische strategie efficiënter zou zijn. Er werden op andere taken geen verschillen gevonden tussen autisten en de controlegroepen, maar dit kan te wijten zijn aan een te geringe gevoeligheid van de batterij voor eventueel aanwezige stoornissen. De expressie-matching taak bijvoorbeeld kan met succes worden uitgevoerd op basis van de opvallende perceptuele kenmerken van een expressie, zonder dat de expressie als zodanig hoeft te worden herkend. Een eventuele stoornis in het herkennen van expressies komt dan niet aan het licht.

In Hoofdstuk 2 werd onderzocht of gezichtsexpressies categorisch worden waargenomen bij gezonde proefpersonen. Hiervoor werd een paradigma gebruikt dat door Etcoff en Magee (1992) is geïntroduceerd in de gezichtswaarnemingsliteratuur. Voor het huidige experiment werden drie continua gecreëerd die liepen van de ene prototypische expressie naar de andere (vrolijk-verdrietig, kwaad-verdrietig en kwaad-angst). Deze stimuli werden aangeboden in twee taken: een identificatietaak en een ABX discriminatietaak. In de identificatietaak moet een proefpersoon voor elke stimulus van een continuüm beoordelen tot welke van de twee expressiecategorieën de stimulus behoord. Op basis van deze resultaten wordt vervolgens de categoriegrens bepaald. De cruciale taak is de discriminatietaak, waarbij steeds twee stimuli van het continuüm moeten worden vergeleken. Er is sprake van categorische perceptie als stimuli die aan weerszijde van de categoriegrens liggen beter van elkaar worden onderscheiden dan stimuli die tot een zelfde categorie behoren. Zowel normale volwassenen als normale kinderen bleken expressies inderdaad categorisch waar te nemen. Om te controleren of de resultaten niet het gevolg waren van dichotomisatie-artefacten werden de stimuli tevens geïnverteerd aangeboden. Het bleek dat in deze conditie tussen-categorie gezichtsparen niet beter van elkaar konden worden onderscheiden dan binnen-categorie paren. Het is dus onwaarschijnlijk dat de resultaten in de normale conditie kunnen worden verklaard door een dichotomisatie-artefact. Tenslotte werden er verschillende aanwijzingen gevonden dat de proefpersonen in staat waren verschillen waar te nemen tussen expressies die binnen eenzelfde categorie vallen: de prestatie op dergelijke paren was boven kansniveau, en expressies die dichter bij het prototype lagen werden sneller herkend en als beter exemplaar van de categorie beoordeeld dan expressies rond de categoriegrens.

In Hoofdstuk 4 werd hetzelfde paradigma als in Hoofdstuk 3 gebruikt om te onderzoeken of de gebrekkige herkenning van emotionele expressies bij autisten te wijten kan zijn aan een stoornis in de categorische perceptie van expressies. Inderdaad bleken autisten de gezichtsuitdrukkingen niet categorisch waar te nemen in de discriminatietaak. Ondanks deze stoornis bleek dat de meeste autisten wel een normaal reactiepatroon vertoonden in de identificatietaak. Alleen een subgroep van autisten die laag scoorde op sociale intelligentie tests had moeilijkheden met het identificeren van de gezichtsexpressies. Het feit dat de overige autisten een normaal reactiepatroon vertoonden in deze taak wijst er op dat zij, mogelijk als gevolg van sociale vaardigheidstrainingen, compensatiestrategieën ontwikkelen die hen in staat stelt gezichtsuitdrukkingen op een andere, niet-categorische, manier te herkennen.

In Hoofdstuk 5 wordt dieper ingegaan op de informatieverwerkingsprocessen die een rol spelen bij het herkennen van gezichtsexpressies en het onthouden van onbekende gezichten. Er worden daarbij twee processen onderscheiden: configurationele en holistische informatieverwerking (Carey & Diamond, 1994).

Het eerste experiment van dit hoofdstuk onderzocht de configurationele verwerking bij autisten. Configurationele verwerking is de codering van een gezicht in het geheugen op basis van zijn configuratie (de onderlinge relaties tussen de constituerende elementen van een gezicht) (Diamond & Carey, 1986). Deze manier van coderen is efficiënter dan het coderen op basis van de afzonderlijke elementen, wat met name blijkt uit het zogenaamde inversie-effect. Dit effect houdt in dat een gezicht veel moeilijker te herkennen is wanneer het ondersteboven wordt gepresenteerd dan in de normale oriëntatie, wat wordt toegeschreven aan het feit dat de configurationele informatie moeilijker toegankelijk is onder deze omstandigheden. Omdat er in de litertuur verschillende aanwijzingen zijn dat autisten relatief goed presteren op inversie-taken, zouden autisten dus misschien minder gebruik maken van de configurationele informatie. Dit werd in dit proefschrift nader onderzocht met een inversietaak met een beperkte geheugenbelasting, zodat eventuele vloereffecten konden worden ondervangen. De resultaten laten zien dat de meeste autisten onder deze omstandigheden een normaal reactiepatroon vertonen: gezichten werden sneller en beter herkend wanneer deze rechtop werden aangeboden dan wanneer ze ondersteboven werden gepresenteerd. Dit effect was voor alle proefpersonen groter voor gezichten dan voor objecten (schoenen). Hoewel het reactiepatroon van autisten en kinderen dus vergelijkbaar was met dat van volwassenen, maakten zij meer fouten en waren langzamer, ondanks het feit dat de presentatietijd van de stimuli langer voor hen was. Autisten en kinderen lijken dus gebruik te maken van de configurationele informatie van een gezicht, maar minder efficiënt dan volwassenen. Een subgroep autisten met een lage sociale intelligentie bleek geen normaal inversie-effect te vertonen. Op grond van de huidige resultaten is het niet duidelijk of dit betekent dat autisten met een meer configurationele verwerkingsstijl gevoeliger zijn voor sociale informatie en dus grotere kans hebben om hun sociale intelligentie te ontwikkelen, of dat tijdens het ontwikkelen van de sociale intelligentie, b.v. als gevolg van sociale vaardigheidstrainingen, meer aandacht ontstaat voor de configurationele informatie van het gezicht.

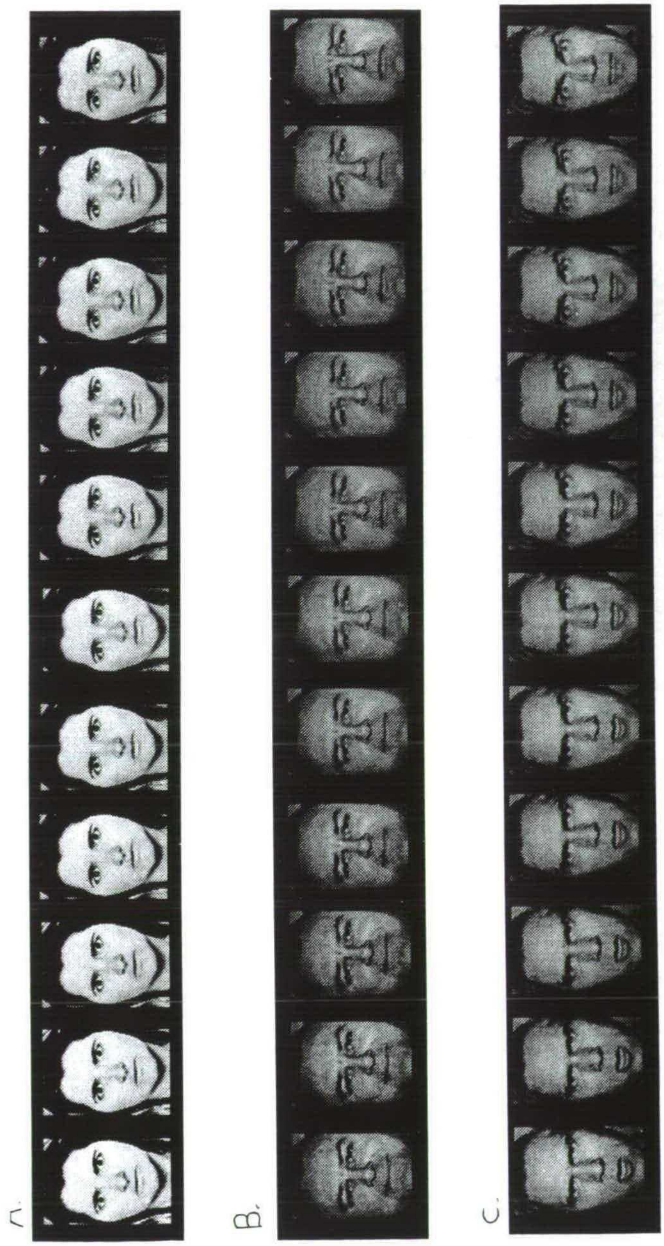
In het tweede experiment van Hoofdstuk 5 werd onderzocht in hoeverre de holistische verwerking van een gezicht verstoord is bij autisten. Tanaka en Farah (1993) concludeerden op basis van hun resultaten dat een gezicht holistisch wordt gerepresenteerd in het geheugen, dat wil zeggen als een geheel (een Gestalt) zonder expliciete representaties van de samenstellende delen. In Hoofdstuk 5 werd met een aangepaste versie van de compositietaak (Young, Hellawell & Hay, 1987) onderzocht of een gezicht ook als een geheel wordt waargenomen. In deze taak wordt bij elke trial eerst een target-gezicht op de monitor gepresenteerd welke de proefpersoon korte tijd moet onthouden. Vlak daarna worden twee compositie-gezichten aangeboden, die zijn samengesteld uit de bovenste en onderste gezichtshelften van verschillende personen. De taak is om te herkennen welke van de twee bovenste gezichtshelften afkomstig is van het target-gezicht. Deze taak is moeilijker als de gezichtshelften precies op elkaar aansluiten, zodat een nieuw gezicht (Gestalt) ontstaat, dan wanneer de helften niet op elkaar aansluiten. Autisten vertoonden, in tegenstelling tot de normale kinderen en volwassenen, geen compositie-effect: zij presteerden even goed op aansluitende compositie-gezichten als op compositie-gezichten waarvan de gezichtshelften niet op elkaar aansloten. Dit suggereert dat autisten gezichten minder als een betekenisvolle eenheid waarnemen dan andere mensen. Dit is in overeenstemming met bevindingen in andere perceptuele taken waarbij een Gestalt moet worden geanalyseerd voor zijn samenstellende delen. Het is echter niet duidelijk of dit ook consequenties heeft voor prestaties op taken die niet primair perceptueel van aard zijn, zoals in een taak waarbij de invloed van de Gestalt-eigenschappen van een stimulus op het geheugen wordt getest. Mermelstein, Prinzmetal en Banks (1979) toonden aan dat het effect van een Gestalt op het taakgedrag verschillend is bij een perceptuele taak dan bij een geheugentaak. Zij vonden in een memory search taak dat de onderdelen van een gezicht beter worden onthouden in de context van een normaal intact gezicht dan in een scrambled gezicht (het zogenaamde 'face superiority effect'), terwijl deze onderdelen in een visual search taak moeilijker worden herkend in de context van een intact gezicht dan in een scrambled gezicht (het zogenaamde 'face inferiority effect').

In Hoofdstuk 6 werd het memory search paradigma van Mermelstein et al. (1979) gebruikt om het face superiority effect bij autisten te onderzoeken. Tevens werd onderzocht of er een 'expression superiority effect' bestaat: een faciliterend effect van een congruente expressie (b.v. blije ogen met een blije mond) ten opzichte van een incongruente expressie (b.v. blije ogen met een droevige mond) op het onthouden en herkennen van de gezichtsonderdelen. Beide effecten werden inderdaad gevonden bij gezonde volwassenen. Ook kinderen en autisten presteerden beter bij intacte gezichten en congruente expressies, maar het effect was kleiner voor deze groepen. De zwakkere configurationele codering bij autisten en kinderen kan hierbij een rol spelen. De configuratie van een scrambled gezicht is verstoord en zal dus slechter verwerkt worden dan de configuratie van een intact gezicht. Als autisten en kinderen minder gebruik maken van configurationele informatie zal daarom een kleiner face superiority effect worden gevonden. Omdat ook expressies op basis van hun configuratie worden onthouden, zal een minder configurationele verwerking bij autisten en kinderen ook leiden tot een kleiner expression superiority effect.

Samenvattend kan worden geconcludeerd dat adolescenten met autisme in sommige opzichten vergelijkbaar zijn met tien jaar oude kinderen in de manier waarop zij gezichten waarnemen, terwijl zij in andere opzichten gezichten kwalitatief anders waarnemen. Zowel kinderen als autisten gebruiken globale scanningsstrategieën wanneer zij gezichten moeten vergelijken, ook wanneer een analytische strategie doelmatiger zou zijn (Hoofdstuk 2). Beide groepen maken weinig efficiënt gebruik van de gezichtsconfiguratie bij het onthouden van een gezicht (Hoofdstukken 5 en 6), waardoor zij onder andere meer moeite dan normale volwassenen hebben om nieuwe gezichten te onthouden. Er zijn twee kwalitatieve verschillen in de gezichtswaarneming tussen autisten en kinderen gevonden in dit proefschrift. Gezichtsuitdrukkingen worden door normale kinderen en volwassenen categorisch waargenomen, maar niet door autisten (Hoofdstukken 3 en 4). Een ander verschil met kinderen is dat autisten een zwakkere Gestalt-waarneming hebben (Hoofdstuk 5). Waarschijnlijk wijst dit op een verstoorde 'concept-driven' perceptie, waardoor minder betekenis aan een stimulus wordt verleend in de waarneming. Mogelijk is deze stoornis ook verantwoordelijk voor de afwezigheid van categorische perceptie bij het herkennen van gezichtsuitdrukkingen, doordat autisten gezichten niet automatisch in expressie-categorieën indelen zoals dat bij andere mensen gebeurt. Het feit dat de sociaal intelligentere autisten toch in staat zijn prototypische gezichtsuitdrukkingen te herkennen wijst er op dat zij compensatiestrategieën hebben ontwikkeld die hen in staat stelt expressies te herkennen op een niet-categorische manier. Deze compensatiestrategieën kunnen in sommige testsituaties onderliggende stoornissen camoufleren, wat de soms tegenstrijdige resultaten in de literatuur kan verklaren. In dit proefschrift zijn methoden uit de cognitieve psychologie toegepast om specifieke gezichtswaarnemingsprocessen bij autisten te onderzoeken, waarbij de invloed van compensatiestrategieën zo veel mogelijk is gereduceerd. Deze aanpak heeft het inzicht in de gezichtswaarneming bij autisten vergroot, en kan ook in de toekomst een waardevolle bijdrage leveren aan een beter begrip van het complexe syndroom autisme.

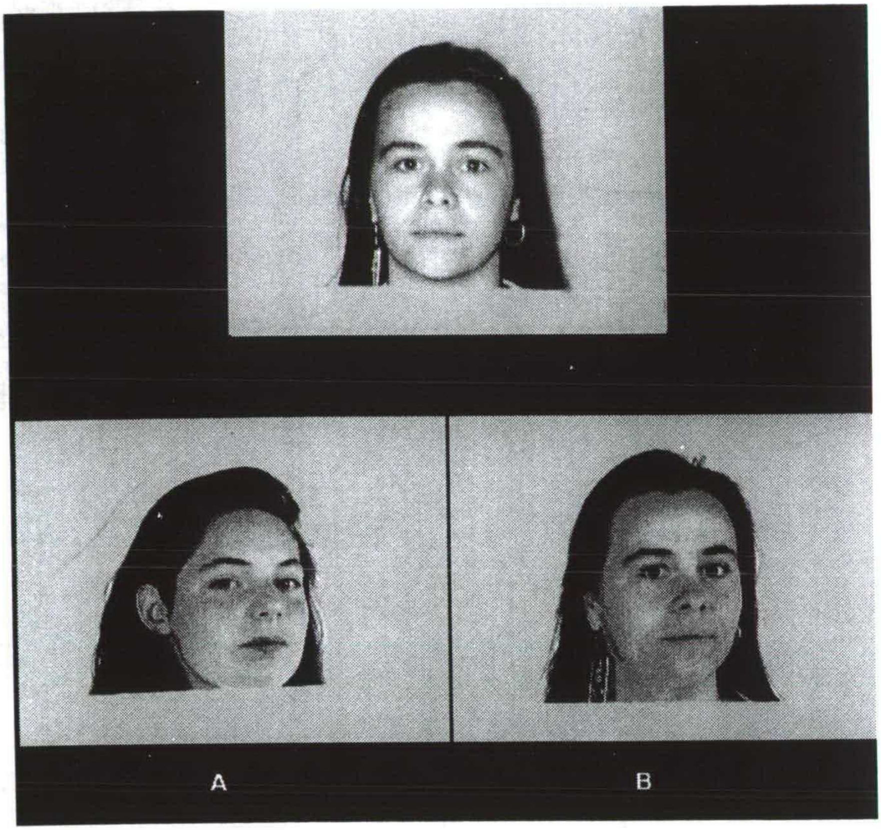
10. Appendixes

10.1. APPENDIX A: STIMULI OF THE CP TASK

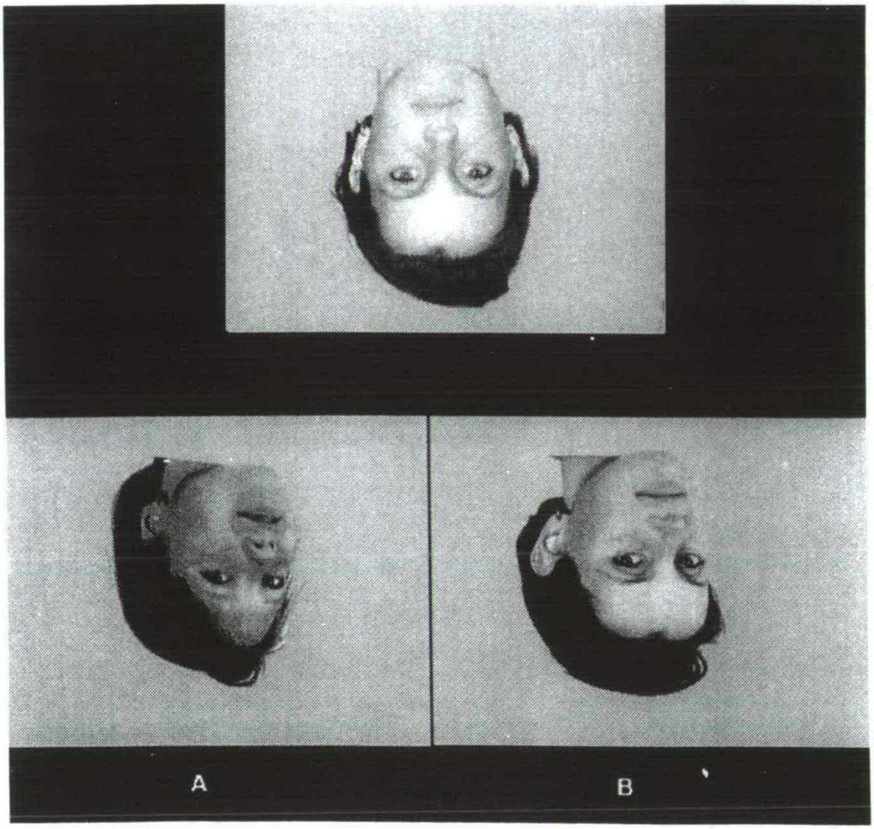


A. Angry (left) to Sad (right)
B. Happy (left) to Sad (right)
C. Angry (left) to Afraid (right)

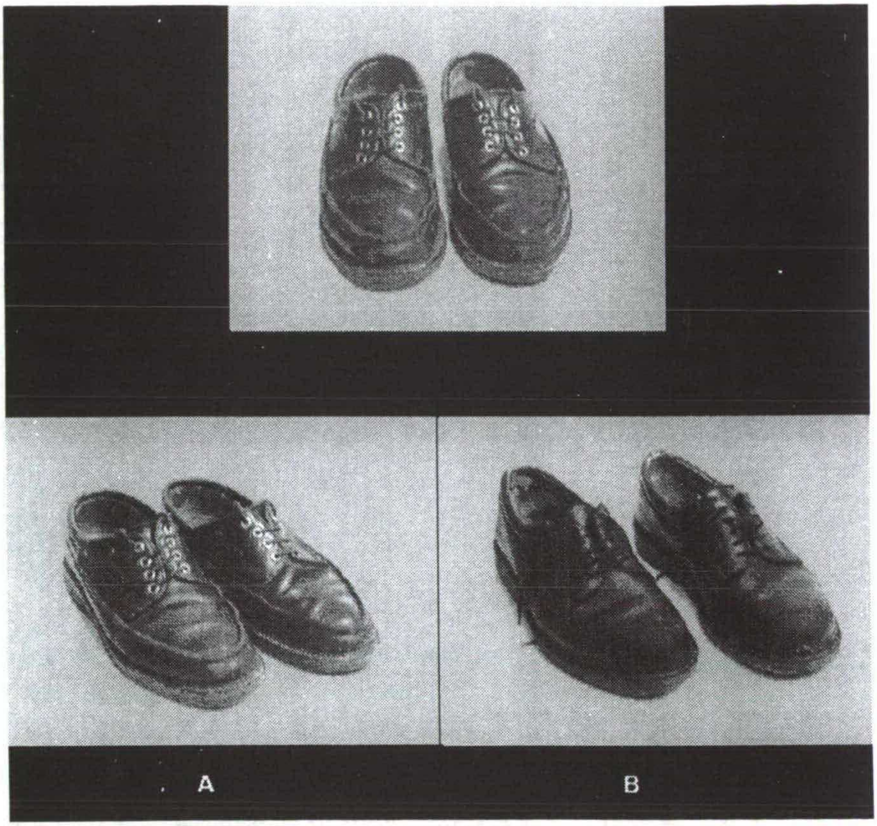
10.2. APPENDIX B: EXAMPLES OF STIMULI OF THE INVERSION TASK



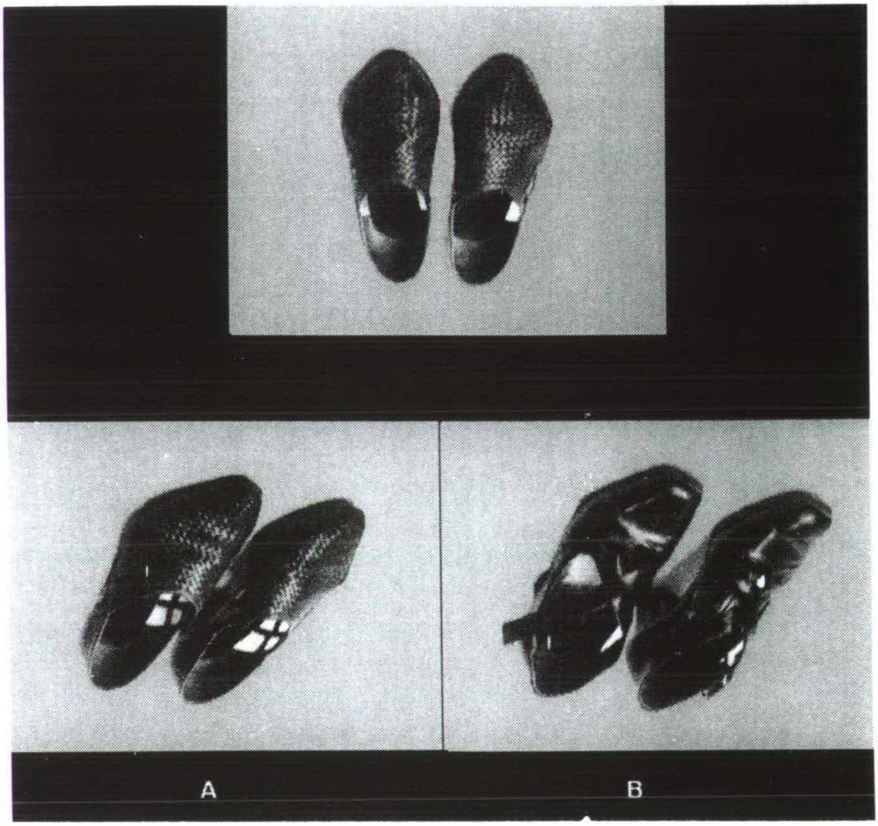
A. Examples of the stimuli of the Upright faces condition in the inversion task (Chapter 5). The upper stimulus is the target stimulus in frontal view, the lower stimuli (A and B) are the test stimuli in 3/4 view.



B. Examples of the stimuli of the Inverted faces condition in the inversion task (Chapter 5). The upper stimulus is the target stimulus in frontal view, the lower stimuli (A and B) are the test stimuli in 3/4 view.



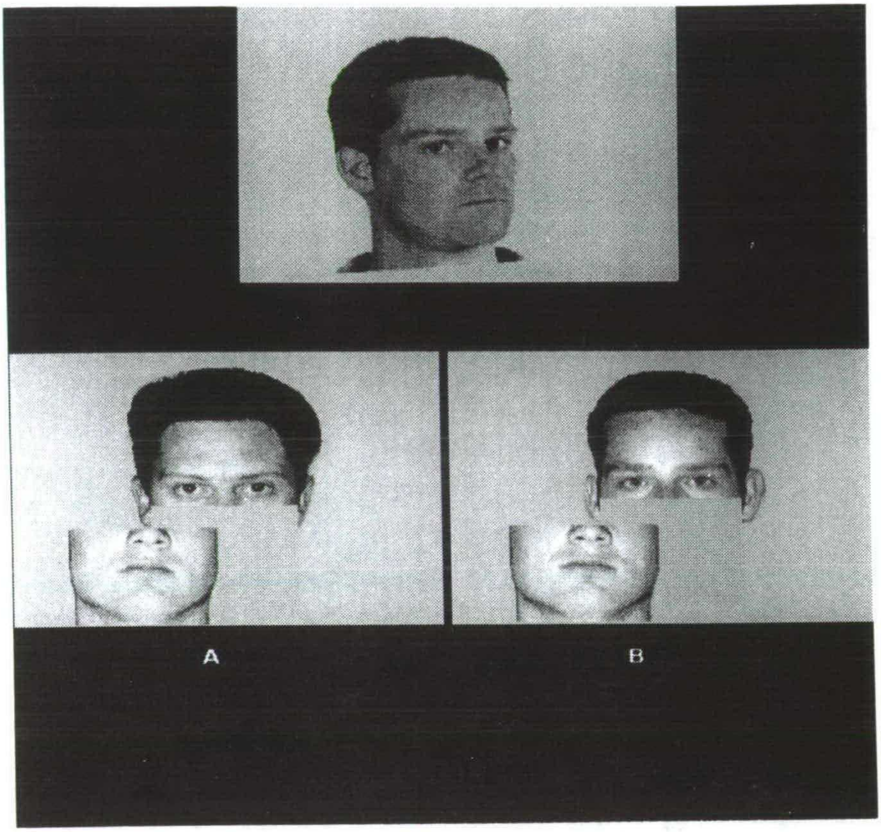
C. Examples of the stimuli of the Upright shoes condition in the inversion task (Chapter 5). The upper stimulus is the target stimulus in frontal view, the lower stimuli (A and B) are the test stimuli in 3/4 view.



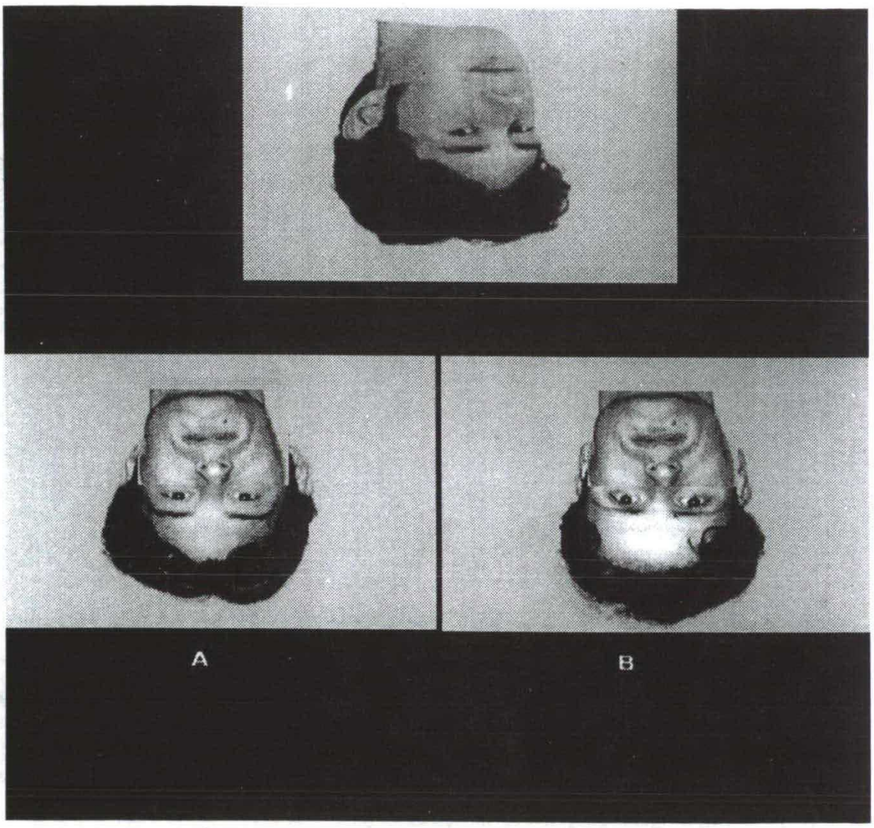
D. Examples of the stimuli of the Inverted shoes condition in the inversion task (Chapter 5). The upper stimulus is the target stimulus in frontal view, the lower stimuli (A and B) are the test stimuli in 3/4 view.

10.3. APPENDIX C: EXAMPLES OF STIMULI OF THE COMPOSITE TASK

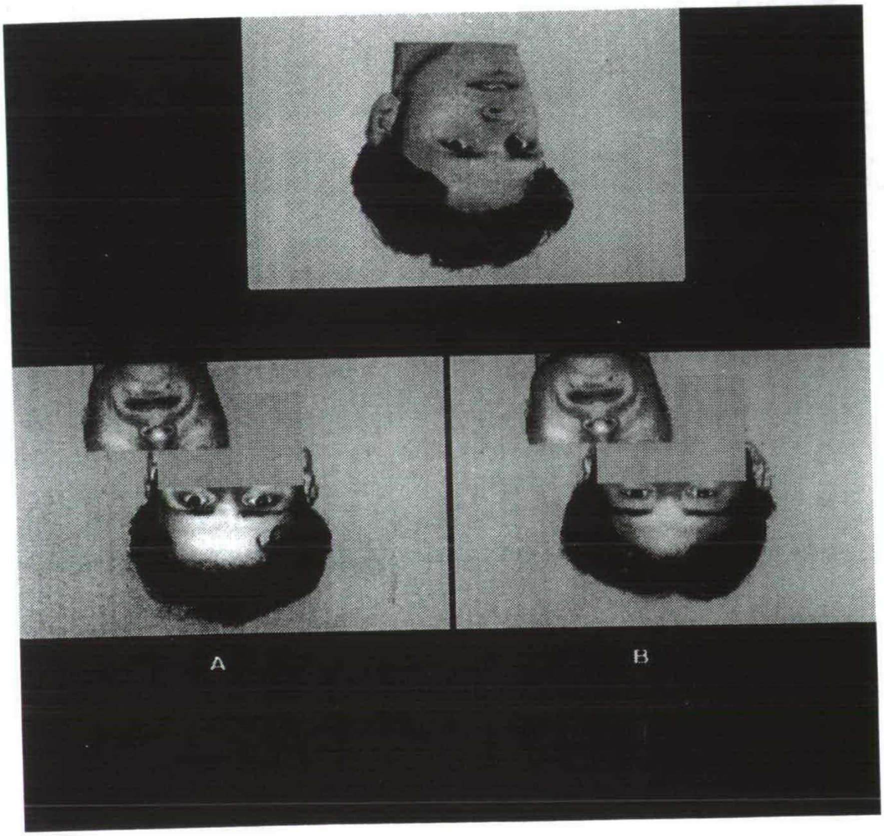
A. Examples of the stimuli of the Upright aligned condition in the composite task (Chapter 5). The upper stimulus is the target stimulus in 3/4 view, the lower stimuli (A and B) are the test stimuli in frontal view.



B. Examples of the stimuli of the Upright nonaligned condition in the composite task (Chapter 5). The upper stimulus is the target stimulus in 3/4 view, the lower stimuli (A and B) are the test stimuli in frontal view.

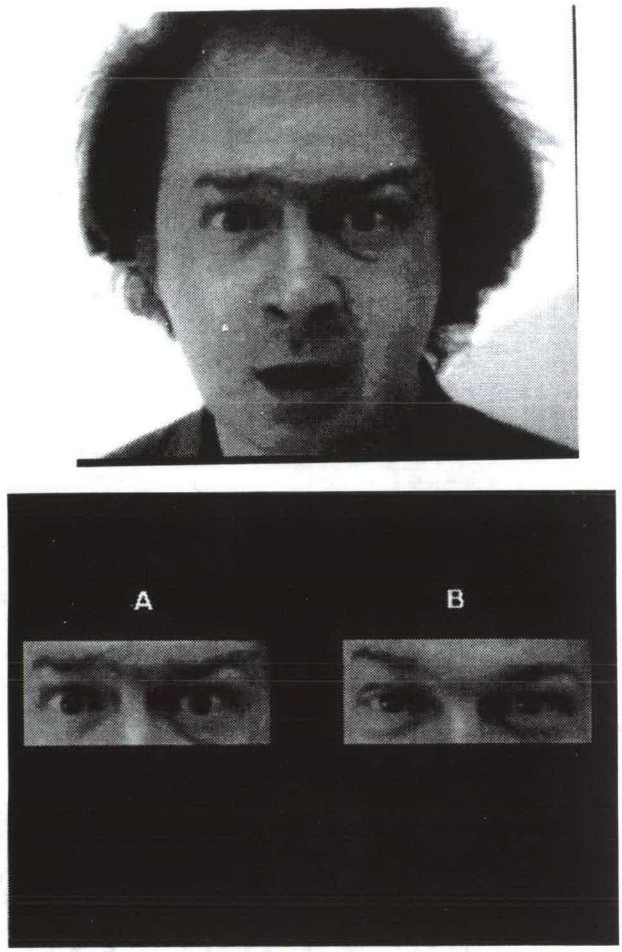


C. Examples of the stimuli of the Inverted aligned condition in the composite task (Chapter 5). The upper stimulus is the target stimulus in 3/4 view, the lower stimuli (A and B) are the test stimuli in frontal view.

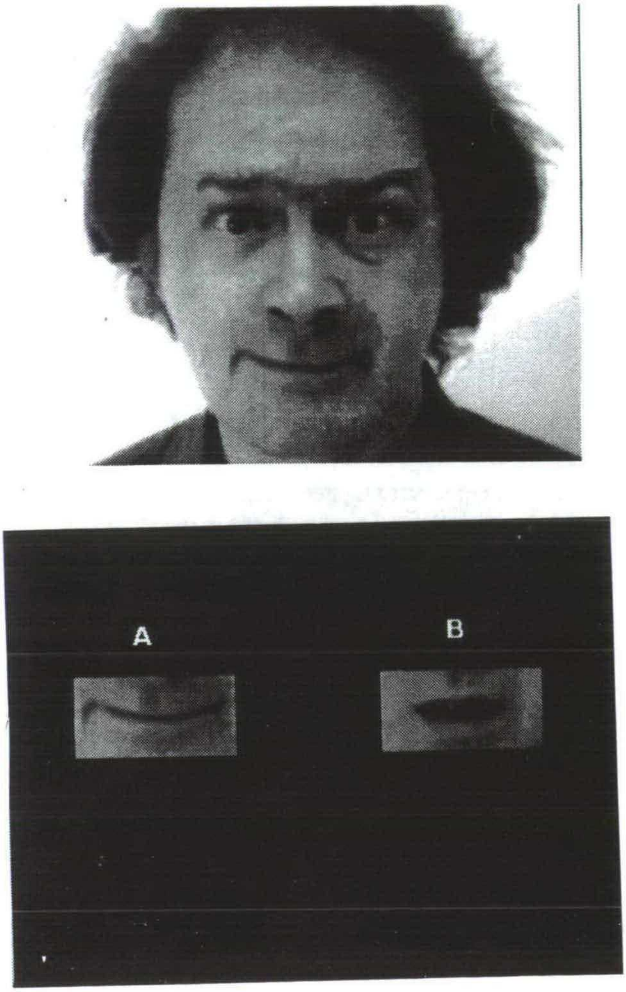


D. Examples of the stimuli of the Inverted nonaligned condition in the composite task (Chapter 5). The upper stimulus is the target stimulus in 3/4 view, the lower stimuli (A and B) are the test stimuli in frontal view.

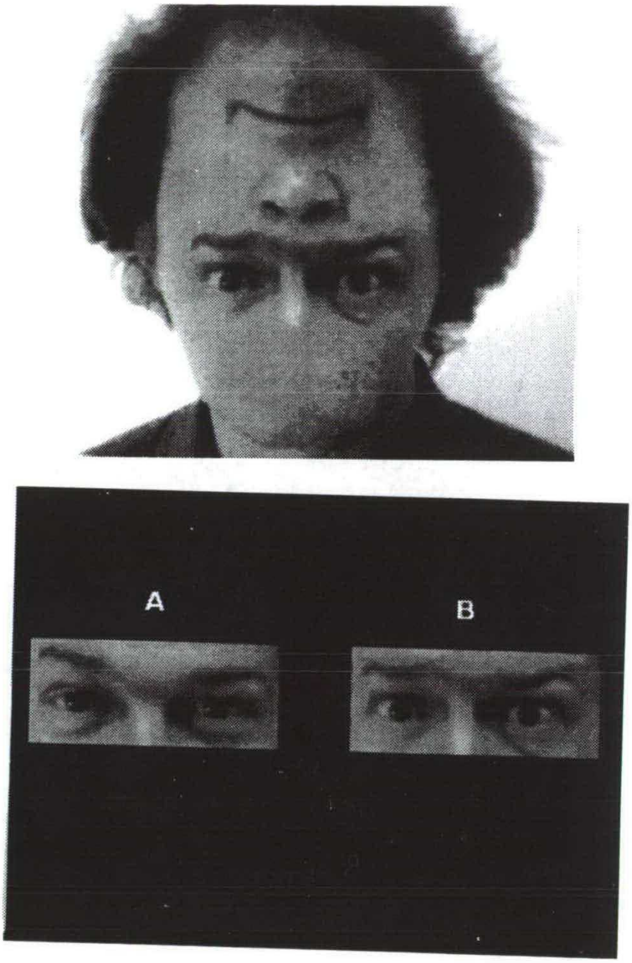
10.4. Appendix D: Examples of stimuli of the memory search task



A. Examples of the stimuli of the Normal face (congruent expression) condition in the memory search task (Chapter 6). The upper stimulus is the target stimulus (normal face), the lower stimuli (A and B) are the test stimuli (facial features).



B. Examples of the stimuli of the Normal face (noncongruent expression) condition in the memory search task (Chapter 6). The upper stimulus is the target stimulus (normal face), the lower stimuli (A and B) are the test stimuli (facial features).



C. Examples of the stimuli of the Scrambled face condition in the memory search task (Chapter 6). The upper stimulus is the target stimulus (scrambled face), the lower stimuli (A and B) are the test stimuli (facial features).

10.5. APPENDIX E: DETAILS OF THE AUTISTIC SUBJECTS

Details of the the autistic subjects from the Dr. Leo Kannerhuis who participated in the experiments of Chapters 4, 5 and 6 are presented in the table on the next page.

The following subjects missed an experiment or were excluded from analyses for that experiment:

- Categorical Perception Task (Chapter 4):
  - Angry-Sad: PP's 1, 2, 4 and 5.
  - Happy-Sad: PP's 10 and 13.
  - Angry-Afraid: PP 10.

- Inversion Task (Chapter 5): PP 3.

- Composite Task (Chapter 5): PP 5.

- Memory Search Task (Chapter 6): PP 4.

pp	Sex (M/F)	Hand (R/L)	Age	Raven (time)	GIT	Social IQ	Diagnosis	Medication
1	M	R	20;5 *middle*	32 (14) *low*	3 *low*	80 *low*	: Retarded/epileptic (MLK school) '91: Autism related disorder (LKH)	dipiperon 2mg/ml 2dd 8 mg, depakine 2x dd 500 mg
2	F	R	16;9 *young*	32 (12) *low*	5 *low*	90 *middle*	: Autistic disorder '91: Autism (LKH)	No
3	M	R	16;4 *young*	45 (17) *high*	1 *low*	50 *low*	'81: MOB : No diagnosis (Sophia Child Hospital) '85: Autism (SARR, orthopedagogist) '90: Autistic disorder (LKH)	4 dd 2 tabl nicotinamide á 50 mg
4	F	R	16;1 *young*	41 (40) *middle*	4 *low*	70 *low*	'85: Retarded (MKD) autism '90: Autism (LKH)	No
5	M	L	19;8 *middle*	37 (11) *low*	4 *low*	95 *middle*	'81: Autism (psychiatrist) '91: Autism (LKH) Remark: formerly epileptic	No
6	F	R	20;8 *old*	43 (51) *middle*	5 *low*	75 *low*	'77: Retarded (KDV) '86: "Borderline" (RIAGG) '87: Autism (RIAGG) '88: Autism (LKH)	No
7	M	R	17;10 *young*	42 (17) *middle*	10 *middle*	85 *low*	'78: Retarded '81: Psychiatric disorder (Sophia Child Hospital) '84: Autism '91: Autism (LKH)	No
8	M	R	18;2 *young*	43 (15) *middle*	13 *high*	110 *high*	'82: MBD (child neurologist) '91: Autism related disorder (child psychiatrist) '92: Autism related disorder (LKH)	Dixarit 0,025 mg 5 tabl
9	M	R	19;6 *middle*	39 (14) *middle*	11 *middle*	100 *middle*	'77: Retarded (KDV) '78: Autism (orthopedagogist) '90: Autism (LKH)	No

pp	Sex (M/F)	Hand (R/L)	Age	Raven (time)	GIT	Social IQ	Diagnosis	Medication
10	M	R	20;8 *old*	38 (22) *middle*	12 *high*	100 *middle*	'78: Autism (KDV) '92: Autism (LKH)	No
11	M	R	20;9 *old*	53 (26) *high*	8 *middle*	105 *high*	'77: Retarded language/speech development (KDV) '78: Autism '89: Autism (LKH)	No
12	M	R	20;7 *old*	55 (12) *high*	17 *high*	105 *high*	'75: "extraordinary" (KDV, MKD) '88: Autism (child psychiatrist) '93: Autism (LKH)	No
13	M	R	24;8 *old*	36 (10) *low*	12 *high*	85 *low*	'82: Autism (RIAGG) '91: Autism (LKH)	No
14	F	R	20;6 *middle*	48 (18) *high*	14 *high*	100 *middle*	'77: Autism (MKD) '89: Autism (AZU) '90: Autism (LKH)	No
15	M	R	18;1 *young*	25 (17) *low*	7 *middle*	115 *high*	'80: Retarded (MOB) '81: Autism (v Berckelaer-Onnes) '91: Autism (LKH)	No
16	M	R	20;10 *old*	48 (37) *high*	7 *middle*	110 *high*	'77: Retarded '85: Autism (psychiatric institutionalized) '91: Autism (LKH) '93: Depression (LKH)	75 mg anafranil dd (antide-pressivum)
17	M	R	18;7 *middle*	34 (45) *low*	15 *high*	105 *high*	'80: MBD (AZG) '85: Dysphatic (child neurologist) '90: PDD-NOS (child neurologist) '90: Autism (LKH)	No

Curriculum Vitae

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1996-	Onderzoeker voor de uitvoering van het project 'cognitieve stijlkenmerken van niet-zwakzinnige autisten' bij de afdeling Medische Psychologie van de Katholieke Universiteit Nijmegen in samenwerking met het Dr. Leo Kannerhuis te Oosterbeek.

ISBN 90-361-0009-7